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INTERACTIVE COMPUTER-AIDED DESIGN AIRCRAFT FLYING QUALITIES PROGRAM. VOLUME IV. PROGRAM ASSESSMENT/ CORRELATION REPORT

G. Place, et al

General Dynamics/Convair

Prepared for:

Aeronautical Systems Division

August 1974

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INTERACTIVE COMPUTER-AIDED DESIGN AIRCRAFT FLYING QUALITIES PROGRAM

VOLUME IV PROGRAM ASSESSMENT/CORRELATION REPORT

G. Place, et al

Prepared by Convair Division of General Dynamics
under AF Contract F33615-74-C-4068

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August 1974

Final Report

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Prepared for
DEPUTY FOR DEVELOPMENT PLANNING
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INTERACTIVE
COMPUTER-AIDED DESIGN
AIRCRAFT FLYING QUALITIES
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INTERACTIVE COMPUTER AIDED DESIGN
AIRCRAFT FLYING QUALITIES PROGRAM

VOLUME I	•	Users Manual
VOLUME II	•	Methods Formulation Manual
VOLUME III	•	Computer Programming Manual
VOLUME IV	•	Program Assessment/ Correlation Report

FOREWORD

This report was prepared by the San Diego Operation of Convair Aerospace Division of General Dynamics Corporation, San Diego, California, under Contract F33615-74-C-4068, Project No. C093. The contract was initiated on 1 January 1974 and was effectively concluded in August 1974 with the submission of this report. The Air Force program study manager was John R. Cathey, ASD/XRHD, Aeronatuical Systems Division, Deputy for Development Planning, Directorate of Advanced Systems Design, Preliminary Design Division, Design Technology Group. The author wishes to thank Mr. Cathey for his able assistance and guidance during the execution of this contract.

The Aircraft Flying Qualities Program was initially developed under Contract F33615-73-C-4081 conducted from 1 January 1973 to 1 September 1973. The study just concluded was for further development and validation of the program's utility and credibility in a preliminary design environment.

Mr. G. Place of the Convair Aerospace Division was the study manager for this study. Significant contributions to the study were made by H. M. Altmann and L.G. Barbee, stability and control, G. F. Campbell, Jr., flying qualities and E.R. Neuharth, computer programming, all of Convair Aerospace Division.

ABSTRACT

This report describes a digital computer program which calculates the longitudinal and lateral-directional stability and control derivatives and aircraft flying qualities for a Mach number range for 0 - 3.0. The report consists of four volumes. Volume I, Users Manual, contains a detailed description of the input/output options, program limitations, input/output data, and a set of sample problems. Volume II, Methods Formulation Manual, outlines the methodology and source, range of applicability, and modifications. Volume III, Computer Programming Manual, outlines the program organization, input/output of each module/subroutine, module or subroutine function, program listings and flow charts. Volume IV, Program Assessment/Correlation Report, presents the results of the correlation studies and conclusions pertaining to the validity of the methodology. The computer program is written in Fortran IV Extended language for the CDC 6600 operating system. However, it is designed to be adapted to other operating systems because use of unique features peculiar to a given processor has been avoided whenever practical. User oriented features are included in the program to provide minimum input data requirements, flexible input/output control options and substitution of experimental data for aerodynamic characteristics.

SUMMARY

Requirements for rapid and economical estimation of aircraft stability and control characteristics and flying quality parameters arise frequently in preliminary design operations. The ability to respond quickly, particularly with the growing emphasis on designing new aircraft to perform specified missions and meet the required design criteria, requires the development of tools to investigate a wide range of vehicle configurations and mission requirements. In view of these requirements, a Flying Qualities Computer program has been developed to facilitate the computation of the longitudinal and lateral-directional stability and control characteristics and aircraft flying qualities.

The Flying Qualities Program employs the methodology or modification of the methodology contained in References 1 - 6. The handling quality methods were derived by applying small perturbation theory to the equations of motion of the aircraft and solving for the transfer functions. (See VOL II, Methods Formulation Manual). These methods define the static stability characteristics at angle-of-attack and in sideslip and the flying quality parameters of MIL-F-8785B and MIL-F-83300.

This report summarizes the Flying Qualities Program to help familiarize the user with the procedures, equations, input/output formats, and the limitations of the program.

The computer program is written in the Fortran IV Extended language for the CDC 6600 operating system. However, it is designed to be adapted to other operating systems because use of special features peculiar to a given processor has been avoided. The program has been developed utilizing the modular concept, so that updating can be confined to changing the internal code of a module without altering its external arrangement.

The modules of the Flying Qualities Program system are divided into three major sections; the aircraft definition section, longitudinal and lateral-directional aerodynamic characteristics section and the aircraft flying qualities section. The airplane definition section describes the aircraft from a geometric consideration in enough detail to perform the necessary aerodynamic computations. The longitudinal and lateral directional characteristics section utilizes the geometric description and evaluates the aerodynamic stability characteristics of the aircraft. The aircraft handling quality parameters are then defined using the modules in the aircraft flying qualities section. Flow through the program is controlled by an executive routine (MØNTØR),

which interrogates the user specified option and directs the flow accordingly.

To permit the use of wind tunnel data or data obtained by the user through other methods, the program provides the option of substituting user input data in lieu of module computed data.

Data input to the program includes basic vehicle geometry, flight conditions and the operation codes for controlling the program operation. Output consists of a geometric description of the aircraft, the corresponding aerodynamic characteristics and the aircraft flying quality parameters.

The Flying Qualities Program is a highly versatile tool that has the capability to estimate the static longitudinal and lateral-directional stability and control characteristics for trimmed and untrimmed flight conditions, the dynamic stability derivatives and aircraft handling qualities over a speed regime of $M = 0.0 - 3.0$.

The program was demonstrated by analyzing configurations in over 125 NASA, NACA, and other technical reports which contained applicable test data. Essentially all program options were exercised within the demonstration cases. These results are compared with test data in Section 2 to supply the reader with information for evaluating the programs capabilities.

The correlation results of the derivatives that most significantly influence aircraft handling qualities are summarized here. If a more complete analysis is required the reader is directed to Section 2.

Longitudinal Derivatives

C_{L_α} - The Aircraft Flying Qualities Program results compare favorably with wind tunnel data with average accuracy levels within ten percent.

X_{ac} - The aerodynamic center location predictability is relatively poor. The average accuracy levels for straight tapered wings is within fifteen percent while for cranked wings it is approximately forty five percent.

C_{m_q} - The pitch damping derivative validation runs resulted in good agreement for some test cases and poor results for others. The cases that indicated poor results illuminated that the wing-body prediction techniques over predict this derivative.

$C_{m_{i_H}}$, $C_{m_{\delta_E}}$ - The comparison of stabilizer and elevator control derivatives with wind tunnel test results show good agreement in the subsonic region. In the transonic and supersonic speed regime the methodology does not account for variations in pressure

distribution in the vacinity of the tail due to inerference effects, therefore, the accuracy levels are more than ten percent.

Lateral-Directional

C_{n_β}, C_{ℓ_β} - The sideslip characteristics demonstration runs indicated poor agreement with wind tunnel test data. The computed values for the yawing moment show an average error of approximately thirty-five percent. The rolling moment predictions show an average error of approximately twenty-five percent.

C_{ℓ_p} - The AFQP does a good job of computing the roll damping derivative with an average accuracy level of approximately nine percent.

C_{n_r} - The average percent error between predicted and test data is approximately thirty-five percent for the yawing moment coefficient due to yaw rate.

$C_{\ell_{\delta_a}}$, $C_{\ell_{\delta_{sp}}}$, $C_{\ell_{\delta_H}}$, $C_{\ell_{\delta_R}}$ - The aileron and spoiler rolling moment correlation results show good agreement for the variety of configurations investigated. The differentially deflected horizontal tail correlation results show relatively poor agreement as was expected due to the methodology being based on many flow dependent variables. The rudder control derivative shows acceptable accuracy for the configurations tested.

The correlation/validation studies have indicated that for some stability and control derivatives the available methodology needs further investigation and modifications made to allow for more acceptable prediction techniques.

The accuracy levels that are presently attainable with the Aircraft Flying Qualities Program do not negate the utility of the program as an acceptable preliminary design tool. The program's utility in preliminary design analyses is demonstrated by the fact that the automation of the available methodology provides for rapid and economical evaluation of an aircraft configuration from a handling qualities standpoint. Alternatively, the use of hand calculations utilizing the same procedures would require expenditures of significant manhours, particularly if the configuration parameters and trade studies are involved or if estimates are desired over a range of flight conditions. The extensive application of complex automated estimation procedures is also prohibitive in terms of time and computer costs in such an environment.

Viable uses of the Flying Qualities Program are demonstrated in (1) providing initial estimates of early predesign configurations, (2) evaluation of effects of configuration changes from a known data base, (3) quick analyses of a configuration to provide guidance to the designer in configuration definition. In the past, the stability and control

engineering analyst had to rely on back of the envelope analysis in order to provide guidance to the design layout engineer. Time after time the analyst would be several configurations behind due to the cumbersome hand computations that were required to provide the data base necessary to evaluate the aircraft handling qualities.

Based on the results of the present correlation studies it is recommended that a detail study be undertaken to provide a significant data base for each derivative that would allow logical modifications of the methodologies.

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SECTION 1

INTRODUCTION

Requirements for rapid and economical estimation of aircraft stability and control characteristics and flying quality parameters arise frequently in preliminary design operations. The ability to respond quickly, particularly with the growing emphasis on designing new aircraft to perform specified missions and meet the required design criteria, requires the development of tools to investigate a wide range of vehicle configurations and mission requirements. In view of these requirements, a Flying Qualities Computer program has been developed to facilitate the computation of the longitudinal and lateral-directional stability and control characteristics and aircraft flying qualities.

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The user of the Flying Qualities Program should study this volume as well as the other three volumes before running a problem. The four volumes present a complete picture of the overall system, with enough information to familiarize the user in all aspects of its design and operation. It is imperative that the user develop a familiarity with the entire system before he runs the program.

The primary purpose of the correlation investigation was to provide a data base to evaluate the validity of the Flying Qualities Program utility and credibility in a preliminary design environment. The scope of the investigation encompassed five general categories including (1) lift and pitching moment characteristics, (2) sideslip characteristics, (3) dynamic derivatives, (4) control effectiveness, and (5) high lift characteristics. Over 125 NASA, NACA and other technical reports containing applicable data were examined during the investigation.

Data references were grouped according to the following categories:

1. High lift characteristics
2. Propeller characteristics
3. Straight tapered wing configurations
4. Non-straight tapered wing configurations
5. Horizontal tail configurations

6. Vertical tail configurations

7. Canard configurations

8. Ventral configurations

The correlation studies were divided into general correlation studies which included the following variables:

1. Body shape

2. Nose shape

3. Wing planform and position

4. Horizontal tail planform and position

5. Vertical tail planform and arrangement

6. High lift characteristics

and specific aircraft configuration correlation studies which included the following aircraft:

1. CV-880, F-4C, F-106

2. AX (Model 70), A-4D, F-102

3. X-3, F-101, F-104

4. NAVION

Considerable use was also made of unpublished test results and studies conducted at Convair Aerospace, San Diego Operation. A complete bibliography of the data reference sources is given in Section 4.

SECTION 2

CORRELATION AND VALIDATION STUDIES

The Flying Qualities Program (FQP) was utilized to estimate the aerodynamic characteristics of a wide variety of configurations to assess the program's utility/credibility in a preliminary design environment and to highlight areas where the available methodology may be deficient. The correlation studies included a literature search to provide a data base with which to compare the estimated values, general parameters correlation studies and specific aircraft correlation studies.

2.1 CORRELATION DATA BASE

A comprehensive literature search was conducted to obtain data on a wide variety of configuration parameters. Over one hundred and twenty five technical reports containing applicable data were examined during the correlation investigation. A bibliography of the data sources is presented in Section 4 of this report. The bibliography was divided into eight categories as listed below:

1. High Lift Characteristics
2. Propeller Characteristics
3. Straight Tapered Wing Configurations
4. Non-Straight Tapered Wing Configurations
5. Horizontal Tail Effects
6. Vertical Tail Effects
7. Canard Configurations
8. Ventral Effects

Some references contain data pertinent to several categories but were listed by priority on scarcity of the data. For instance, a straight taper wing configuration may have various horizontal tail heights and since data on tail height variation is not as plentiful as basic straight wing data, the report would be listed under Category 5.

In the correlation substantiation tables the references will correspond to the above categories. Therefore, Reference 4.1 would refer to Category 4 Reference 1.

The number of variables and the time limit did not allow every data reference to be analyzed. A number of different configurations from each category was analyzed to

provide a basis for making decisions on methodology accuracy and recommendations. Table 2-1 presents the data references utilized and the relevant aerodynamic characteristics for each data source.

2.2 GENERAL AIRCRAFT CONFIGURATION CORRELATION STUDIES

The basic approach of the general configuration correlation studies was to utilize reference sources that had systematically varied a configuration parameter and evaluate the capability of the Flying Qualities Program to predict the trends in the various aerodynamic characteristics associated with the particular parameter being varied.

The configuration parameters that were considered are:

1. Body Shape
2. Nose Shape
3. Wing Planform
   a. Aspect Ratio
   b. Taper Ratio
   c. Sweep
   d. Straight Tapered
   e. Non-Straight Tapered
4. Wing Position
5. Horizontal Tail Planform and Position
6. Vertical Tail Planform Arrangements
7. High Lift System Arrangements

The above parameters do not necessarily affect all the aerodynamic characteristics, therefore, each characteristic is discussed as a separate entity. The aerodynamic characteristics are divided into the following categories:

1. Lift Characteristics
2. Pitching Moment Characteristics
3. Sideslip Characteristics
4. Dynamic Stability Characteristics
   a. Longitudinal
   b. Lateral-Directional

5. Control Effectiveness

6. High Lift Characteristics

Each of these categories will be discussed in the following sections.

2.2.1 <u>LIFT CHARACTERISTICS.</u> Tables 2-2 through 2-7 summarize the results of the correlation studies of the lift curve slope. Most of the configurations analyzed had wings that were mounted at the fuselage centerline with no camber or twist, therefore, the zero lift angle of attack was zero.

2.2.1.1 <u>Straight Tapered Wing Planform Characteristics.</u> Table 2-2 presents the results for a group of straight tapered wing aircraft configurations that cover a wide range of planform geometry:

Ref.	AR	λ	Λ_{LE}	t/c
3.21	2.31	0.0	60.0°	0.03
3.29	2.0	0.0	63.4°	0.05
3.35	2.2	0.0	60.0°	0.04
3.36	5.9	0.474	0.0°	0.12
6.1	3.86	0.262	49.0°	0.07

The data for Reference 3.21 also presents the effect of body fineness ratio (6.0-12.0) and wing position. The data indicates that these two parameters have a relatively insignificant effect on the lift curve slope.

The overall accuracy (presented as the average percent error) is quite good, for most cases well within ten percent. The maximum error encountered was 11.5 percent. Table 2-3 presents the results of an investigation to assess the effects of sweep, taper ratio and horizontal tail position on the lift curve slope of straight tapered wing configurations. The configurations exhibited the following planform geometry:

Ref.	AR	λ	Λ_{LE}	t/c
3.14	3.0	0.4	19.1	0.03
↓	↓	↓	45.0	↓
↓	↓	↓	53.1	↓
↓	↓	0.2	↓	↓
↓	↓	0.0	↓	↓
4.1	↓	0.4	45	0.05
↓	↓	↓	53	↓
5.6	4.0	0.3	48.6	0.05

The lift curve slope methodology appears to evaluate the effects of sweep, taper ratio and tail position within reasonable accuracy. For most cases investigated the

percentage error was within ten percent.

The effects of two body shapes and several empennage arrangements are tabulated in Table 2-4. The accuracy is within ten percent except for the high transonic Mach number of 0.94. Predictably, the accuracy deteriorates as the Mach number approaches one due to the section lift curve slope. The Mach number effect on the lift curve slope should only be used up to the critical Mach number which is well below M = 0.94.

Tables 2-5 and 2-6 present the results of the correlation studies of the highly tapered and swept wing configurations of Reference 5.2. The planform parameters covered are :

Config.	AR	λ	Λ_{LE}	t/c
High Taper	3.0	0.143	38.7	0.06
Swept	4.0	0.30	48.6	0.06

The body nose length, fuselage length and fineness ratio were varied utilizing both wing planforms. The accuracy levels for the swept wing is better than the high taper wing. The average error for the swept and highly tapered is 3.3 and 8.4 respectively.

The accuracy level exhibited by the highly tapered wing of this series is not reflected in the previous series (Ref. 3.14), which had accuracy levels of 5.87 and 2.76 for taper ratios of 0.0 and 0.2 respectively.

2.2.1.2 Cranked Wing Planforms. The results of the cranked wing planform correlation studies are presented in Table 2-7. The planform parameters covered are summarized below:

Ref.	AR	λ	Λ_{LE_I}	Λ_{LE_O}	t/c
4.1	2.91	0.4	53.1	32.2	0.05
	↓	↓	↓	43.2	
4.7	5.2	0.09	60	25	
	2.1	0.184		75	
	4.49	0.160		30	
	1.75	0.239	↓	70.5	↓
5.6	4.0	0.3	48.6	7.7	0.06

The average error was 4.9 percent with the maximum error from +9.4 to -20.3. The largest percent error is exhibited by the 53-32 + Tail configuration of Reference 4.1.

The effect of horizontal tail position is also presented for the configuration of Reference 5.6. The data indicates good correlation with variations in tail position over the flight regime investigated.

The results presented for Reference 4.7 are for two variable wing sweep configurations simulated by the cranked wing methodology. The overall accuracy level of 7.96 percent is not as good as the basic cranked wing results, but indicates that this type of representation provides reasonable results.

Table 2-1. Correlation Data Source

References	Data Type										
	Lift/Pitch	Sideslip	Longitudinal* Dynamic	Lateral - * Directional Dynamic	Control Effectiveness **						High Lift Characteristics
					a	sp	DH	E	ST	R	
1.1	(NOT USED)										
1.2									x		
1.3											x
2.1								x			
2.2	(NOT USED)										
3.1	(NOT USED)										
3.2					x	x					
3.3	(NOT USED)										
3.4											
3.5											
3.6	x			x							
3.7	(NOT USED)										
3.8											
3.9											
3.10											
3.11							x				
3.12	(NOT USED)										
3.13											
3.14	x										
3.15	(NOT USED)										
3.16											
3.17					x						
3.18		x			x		x			x	
3.19	(NOT USED)										

Table 2-1. Correlation Data Source (Contd)

References	Data Type										
	Lift/Pitch	Sideslip	Longitudinal* Dynamic	Lateral - * Directional Dynamic	Control Effectiveness **						High Lift Characteristics
					a	sp	DH	E	ST	R	
3.20		x									
3.21	x	x									
3.22	(NOT USED)										
3.23	(NOT USED)										
3.24					x	x					
3.25	(NOT USED)										
3.26											
3.27											
3.28											
3.29	x	x			x					x	
3.30		x			x					x	
3.31	(NOT USED)										
3.32											
3.33											
3.34											
3.35	x	x	x	x				x			
3.36	x	x		x							
3.37	x	x	x	x							
3.38				x							
3.39	(NOT USED)										
3.40			x								
3.41	x								x		
3.42	x										
3.43	x	x			x				x		
3.44	x	x	x	x	x				x		
3.45	x								x		
3.46	x	x	y	y	x	x		x		x	

Table 2-1. Correlation Data Source (Contd)

References	Data Type										
	Lift/Pitch	Sideslip	Longitudinal* Dynamic	Lateral - * Directional Dynamic	Control Effectiveness **						High Lift Characteristics
					a	sp	DII	E	ST	R	
3.47								x			
3.48	(NOT USED)										
3.49											
3.50											
3.51	x	x		y	x			x		x	
3.52	x	x	y	y	x	x		x		x	
3.53	x	x	y	y	x			x		x	
3.54	(NOT USED)										
3.55	x	x	y	y					x	x	
3.56	x	x	x	x	x					x	
4.1	x										
4.2	x										
4.3	(NOT USED)										
4.4											
4.5											
4.6											
4.7	x	x									
4.8	(NOT USED)										
4.9											
4.10											
4.11											
4.12											
4.13											
5.1	x	x	x	x					x		
5.2	x										

Table 2-1. Correlation Data Source (Contd)

References	Data Type										
	Lift/Pitch	Sideslip	Longitudinal* Dynamic	Lateral - * Directional Dynamic	Control Effectiveness **						High Lift Characteristics
					a	sp	DH	E	ST	R	
5.3	(NOT USED)										
5.4											
5.6	x	x									
5.7	(NOT USED)										
5.8		x									
5.9	x	x									
5.10	(NOT USED)										
6.1	x	x			x					x	
6.2	(NOT USED)										
6.3											
6.4	x	x							x		
6.5	x										
6.6	(NOT USED)										
6.7											
7.1	(NOT USED)										
7.2											
7.3											
7.4											
8.1a									x		
8.1b	(NOT USED)										

*x — Test Data
y — Estimated Data

** a — Aileron effectiveness
sp — Spoiler
DH — Differentially deflected horizontal
E — Elevator effectiveness
ST — Stabilizer effectiveness
R — Rudder effectiveness

TABLE 2-2

Lift Characteristics of Straight Tapered Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg $^{-1}$) Calc	C_{L_α} (deg $^{-1}$) Test	Percent Error	α_{L_0} (deg) Calc	α_{L_0} (deg) Test	Percent Error	Comment
6.1	Basic	1.61	.0543	.0545	-.36	0.0	0.0	-	Vertical Tail Effect is Insignificant
		2.01	.0446	.0450	-.89		-.025		
3.29	WB	.13	.0399	.037	7.8	0.0	0.0	-	
	WBV		.0399	.037	7.8				
	WBHV		.0457	.041	11.5				
3.21	W1+F1	0.17	.0439	.044	-.22	0.0	0.0	-	Mid Wing
	+F2		.0437		-.68				
	+F3		.0430		-2.3				
	W2+F1		.0439	.042	4.5		.5		High Wing
	+F2		.0437		4.0		.5		
	+F3		.0430	.041	4.9		1.0		
	W3+F1		.0439	.045	-2.4		0		Low Wing
	+F2		.0437		-2.9		0		
	+F3		.0430		-4.4		.2		
3.35	WBV	0.25	.0418	.0400	4.5	0.0	0.0	-	
		0.60	.0431	.0420	2.6				
		0.85	.0495	.0490	1.0				
		0.92	.0513	.0500	2.6				
		0.94	.0518	.0510	1.6				
3.36	WF	.17	.0831	.0770	7.9	0.0	1.0	-	
	WFHV		.0927	.0850	9.1		.04		

TABLE 2-3

Lift Characteristics of Straight Taper Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	α_{L_o} -(deg) Calc	α_{L_o} -(deg) Test	Percent Error	Comment
4.1	45	0.60	.0587	.0590	-0.5	0.0	0.0	—	(Tail-Off)
		0.80	.0659	.0660	-0.2				
		0.90	.0694	.0710	-2.3				
		1.02	.0725	.0770	-5.8				
		1.20	.0625	.0690	-9.4				
		1.40	.0504	.0570	-11.6				
	53	0.60	.0535	.0580	-7.8				
		0.80	.0589	.0610	-3.4				
		0.90	.0615	.0620	-0.8				
		1.02	.0638	.0650	-1.9				
		1.20	.0564	.0620	-9.0				
		1.40	.0495	.0560	-11.6				
	53 + Tail	0.60	.0560	.0620	4.4				(Tail-On)
		0.80	.0599	.0650	4.5				
		0.90	.0739	.0675	2.8				
		1.02	.0649	.0780	-11.7				
		1.20	.0590	.0775	-17.8				
		1.40	.0540	.0700	-18.1				
5.6	Swept	0.80	.0732	.0700	4.6				(Tail-Off)
		0.85	.0753	.0720	4.6				
		0.90	.0773	.0770	0.4				
		0.92	.0781	.0790	-1.1				
		0.80	.0765	.0750	2.0				(Center Horizontal Position)
		0.85	.0784	.0770	1.8				
		0.90	.0802	.0800	0.3				
		0.92	.0809	.0820	-1.3				

TABLE 2-3 (Contd)

Lift Characteristics of Straight Taper Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	Test	Percent Error	α_{L_0} -(deg) Calc	Test	Percent Error	Comment
		0.80	.0787	.0790	-0.4	0.0	0.0	—	(Mid Horizontal Position)
		0.85	.0806	.0800	0.8				
		0.90	.0825	.0820	0.6				
		0.92	.0833	.0850	-2.0				
5.6	Swept	0.80	.0804	.0810	-0.7				(High Horizontal Position)
		0.85	.0824	.0820	0.5				
		0.90	.0845	.0850	-0.6				
		0.92	.0853	.0870	-1.9				
3.14	Sweep(19.1)	0.60	.0688	.0660	4.24				(Tail-Off)
		0.90	.0852	.0740	15.14				
		1.02	.0869	.0850	2.24				
		1.20	.0819	.0780	5.00				
		1.40	.0725	.0640	13.28				
	Sweep(45.0)	0.60	.0587	.0580	1.21				
		0.90	.0685	.0700	-2.14				
		1.02	.0713	.0780	-8.59				
		1.20	.0654	.0680	-3.82				
		1.40	.0525	.0560	-6.25				
	Sweep(53.1) Taper(0.4)	0.60	.0534	.0520	2.69				
		0.90	.0606	.0590	2.71				
		1.02	.0626	.0640	-2.19				
		1.20	.0589	.0580	1.55				
		1.40	.0515	.0520	-0.96				
	Taper (0.0) Sweep(53.1)	0.60	.0573	.0520	10.2				
		0.90	.0672	.0605	11.1				

TABLE 2-3 (Contd)

Lift Characteristics of Straight Taper Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1})		Percent	α_{L_0} -(deg)		Percent	Comment
			Calc	Test	Error	Calc	Test	Error	
		1.02	.0695	.0700	-0.71	0.0	0.0	—	(Tail-Off)
		1.20	.0639	.0620	3.06				
		1.40	.0517	.0540	-4.26				
	Taper (0.2)	0.60	.0551	.0540	2.04				
	Sweep(53.1)	0.90	.0632	.0620	1.94				
		1.02	.0653	.0700	-6.70				
		1.20	.0611	.0610	0.16				
		1.40	.0524	.0540	-2.96				

TABLE 2-4

Lift Characteristics of Straight Taper Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg - 1) Calc	C_{L_α} (deg - 1) Test	Percent Error	α_{oL_O} (deg) Calc	α_{oL_O} (deg) Test	Percent Error	Comment	
5.9	Tail-Off	0.6	.0612	.063	-2.9	0.0	0.0	-	Tapered Body	(Tail-Off)
		0.8	.0692	.0645	9.6					
		0.94	.0733	.0690	6.2					
	Tail 1	0.6	.0696	.0710	-1.9					(T-Tail)
		0.8	.0782	.0735	6.4					
		0.9	.0823	.0750	9.7					
		0.94	.0840	.0950	-11.6					
	Tail 2	0.6	.0651	.0645	0.9					(Conventional Tail)
		0.8	.0727	.0690	5.4					
		0.9	.0763	.0735	3.8					
		0.94	.0778	.0930	-16.3					
	Tail 3	0.6	.0651	.0660	-1.4					(Equal Semispans)
		0.8	.0727	.0680	6.9					
		0.9	.0763	.0725	5.2					
		0.94	.0778	.0880	-11.6					
	Tail 3	0.6	.0649	.0660	-1.7				Cylindrical Body	
		0.8	.0724	.0680	6.5					
		0.9	.0761	.0725	4.9					
		0.94	.0775	.0880	-11.9					
	Tail 4	0.6	.0651	.0710	-8.3				Tapered Body	(+ - Tail)
		0.8	.0727	.0735	-1.1					
		0.9	.0763	.0750	1.7					
		0.94	.0778	.0950	-18.1					
	Tail 5	0.6	.0660	.069	-4.3					(H - Tail)
		0.8	.0734	.074	-0.8					
		0.9	.0770	.0795	-3.2					
		0.94	.0785	.0930	-15.6					

TABLE 2-5

Lift Characteristics of Highly Tapered Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	α_{L_0} (deg) Calc	α_{L_0} (deg) Test	Percent Error	Comment
5.2	WFO	0.60	0.0618	0.059	4.8	0	-0.1	-100	F0, F1, and F2 Form A, Nose Length Series
		0.80	0.0725	0.064	13.3		-0.1	-100	
		0.85	0.751	0.067	12.1		-0.2	-100	
		0.90	0.778	0.074	5.4		-0.2	-100	
		0.92	0.789	0.078	1.2		-0.2	-100	
	WF0VH	0.60	0.0699	0.065	7.5		0	0	
		0.80	0.0811	0.073	11.1				
		0.85	0.0839	0.075	11.9				
		0.90	0.0866	0.078	11.0				
		0.92	0.0877	0.084	4.4				
	WF1	0.60	0.0618	0.059	4.8		-0.1	-100	
		0.80	0.0725	0.064	13.3		-0.1	-100	
		0.85	0.0751	0.067	12.1		-0.2	-100	
		0.90	0.0778	0.074	5.4		-0.2	-100	
		0.92	0.0789	0.078	1.2		-0.2	-100	
	WF1VH	0.60	0.0699	0.065	7.5		0	0	
		0.80	0.0811	0.073	11.1				
		0.85	0.0839	0.075	11.9				
		0.90	0.0866	0.078	11.0				
		0.92	0.0877	0.084	4.4		0	0	
	WF2	0.60	0.0618	0.059	4.8				
		0.80	0.0725	0.064	13.3		-0.1	-100	
		0.85	0.0751	0.067	12.1		-0.2	-100	
		0.90	0.0778	0.074	5.4		-0.2	-100	
		0.92	0.0789	0.078	1.2		-0.2	-100	

TABLE 2-5 (Contd)

Lift Characteristics of Highly Tapered Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	$\alpha^{\bullet}_{L_o}$ (deg) Calc	$\alpha^{\bullet}_{L_o}$ (deg) Test	Percent Error	Comment
5.2	WF2VH	0.60	0.0699	0.065	7.5	0	0	0	F0, F1, and F2 Form A, Nose Length Series
		0.80	0.0811	0.073	11.1				
		0.85	0.0839	0.075	11.9				
		0.90	0.0866	0.078	11.0				
		0.92	0.0877	0.084	4.4				
	WF3	0.60	0.0618	0.059	4.8		-0.3	-100	F3, F4, and F5 Form A Fuselage Length Series
		0.80	0.0725	0.064	13.3		-0.2	-100	
		0.85	0.0751	0.067	12.1		-0.2	-100	
		0.90	0.0778	0.074	5.4		-0.1	-100	
		0.92	0.0789	0.078	1.2		-0.2	-100	
	WF3VH	0.60	0.0699	0.065	7.5		0	0	
		0.80	0.0811	0.073	11.1				
		0.85	0.0839	0.075	11.9				
		0.90	0.0866	0.078	11.0				
		0.92	0.0877	0.084	4.4				
	VF4	0.60	0.0618	0.059	4.8		0	0	F4, F2, and F1 Form A Nose-Fineness-Ratio Series
		0.80	0.0725	0.064	13.3		-0.1	-100	
		0.85	0.0751	0.067	12.1		-0.2	-100	
		0.90	0.0778	0.074	5.4		-0.1	-100	
		0.92	0.0789	0.078	1.2		-0.2	-100	
	VF4VH	0.60	0.0699	0.065	7.5		1.0	100	
		0.80	0.0811	0.073	11.1		.2	100	
		0.85	0.0839	0.075	11.9		0	0	
		0.90	0.0866	0.078	11.0				
		0.92	0.0877	0.084	4.4				

TABLE 2-5 (Contd)

Lift Characteristics of Highly Tapered Wing Configurations Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	α_{L_0} (deg) Calc	α_{L_0} (deg) Test	Percent Error	Comment
5.2	VF5	0.60	0.0618	0.059	4.8	0	-0.1	-100	F4, F2, and F1 Form A Nose-Fineness-Ratio Series
		0.80	0.0725	0.064	13.3		-0.1	-100	
		0.85	0.0751	0.067	12.1		-0.2	-100	
		0.90	0.0778	0.074	5.4		-0.1	-100	
		0.92	0.0789	0.078	1.2		-0.2	-100	
	VF5VH	0.60	0.0699	0.065	7.5		0.2	100	
		0.80	0.0811	0.073	11.1		0	0	
		0.85	0.0839	0.075	11.9				
		0.90	0.0866	0.079	11.0				
		0.92	0.0877	0.084	4.4				

TABLE 2-6

Lift Characteristics of Swept Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	α_{L_0} (deg) Calc	α_{L_0} (deg) Test	Percent Error	Comment
5.2	WFO	0.80	0.0707	0.068	4.0	0	-0.2	-100	F0, F1, and F3 Form A Nose Length Series
		0.85	.0728	-	-		-	-	
		0.90	0.0749	0.075	-0.1		-0.2	-100	
		0.92	0.0757	-	-		-	-	
	WF0VH	0.80	0.0737	0.071	3.8		0	0	
		0.085	0.0756	0.075	0.8				
		0.90	0.0776	0.082	-5.4				
		0.92	0.0783	0.083	-5.7				
	WF1	0.80	0.0707	0.068	4.0		-0.4	-100	
		0.85	0.0728	-	-		-	-	
		0.90	0.0749	0.075	-0.1		-0.4	-100	
		0.92	0.0757	-	-		-	-	
	WF1VH	0.80	0.0737	0.071	3.8		0	0	
		0.85	0.0756	0.075	0.8				
		0.90	0.0776	0.082	-5.4				
		0.92	0.0783	0.083	-5.7				
	WF2	0.80	0.0707	0.068	4.0		-0.3	-100	
		0.85	0.0728	-	-		-	-	
		0.90	0.0749	0.075	-0.1		-0.3	-100	
		0.92	0.0757	-	-		-	-	
	WF2VH	0.8C	0.0737	0.071	3.8		0	0	
		0.85	0.0756	0.075	0.8				
		0.90	0.0776	0.082	-5.4				
		0.92	0.0783	0.083	-5.7				

TABLE 2-6 (Contd)

Lift Characteristics of Swept Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	$\alpha^\circ_{L_0}$ (deg) Calc	$\alpha^\circ_{L_0}$ (deg) Test	Percent Error	Comment
5.2	WF3	0.80	0.0707	0.068	4.0	0	-0.3	-100	F3, F4, and F5 Form A Fuselage Length Series
		0.85	0.0728	-	-		-	-	
		0.90	0.0749	0.075	-0.1		-0.3	-100	
		0.92	0.757	-	-		-	-	
	WF3VH	0.80	0.0737	0.071	3.8		0	0	
		0.85	0.0756	0.075	0.8				
		0.90	0.0776	0.082	-5.4				
		0.92	0.0783	0.083	-5.7				
	WF4	0.80	0.707	0.068	4.0		-0.3	-100	F4, F2, and F1 Form A Nose-Fineness-Ratio Series
		0.85	0.728	-	-		-	-	
		0.90	0.749	0.075	-0.1		-0.3	-100	
		0.92	0.757	-	-		-	-	
	WF4VH	0.80	0.0737	0.071	3.8		0	0	
		0.85	0.0756	0.075	0.8		0.1	100	
		0.90	0.0776	0.082	-5.4		0.2	100	
		0.92	0.0783	0.083	-5.7		0.3	100	
	VF5	0.80	0.0707	0.068	4.0		-0.2	-100	
		0.85	0.0728	-	-		-	-	
		0.90	0.0749	0.075	-0.1		-0.2	-100	
		0.92	0.0757	-	-		-	-	
	VF5WB	0.80	0.0737	0.071	3.8		0	0	
		0.85	0.0756	0.075	0.8				
		0.90	0.0716	0.082	-5.4				
		0.92	0.0783	0.083	-5.7				

TABLE 2-7

Lift Characteristics of Cranked Wing Configurations
Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	α_{L_0} -(deg) Calc	α_{L_0} -(deg) Test	Percent Error	Comment
4.1	53-32	0.60	.0623	.0595	4.7	0.0	0.0	—	(Tail-Off)
		0.80	.0656	.0650	0.9				
		0.90	.0672	.0720	-6.7				
		1.02	.0687	.0750	-8.4				
		1.20	.0605	.0650	-6.9				
		1.40	.0530	.0560	-5.4				
	53-43	0.60	.0608	.0580	4.8				
		0.80	.0637	.0615	3.6				
		0.90	.0651	.0660	-1.4				
		1.02	.0663	.0720	-7.9				
		1.20	.0588	.0650	-9.5				
		1.40	.0524	.0560	-6.4				
	53-32 + Tail	0.60	.0647	.0640	1.1				(Tail-On-Mid Location)
		0.80	.0679	.0690	1.6				
		0.90	.0694	.0720	-3.2				
		1.02	.0708	.0840	-15.7				
		1.20	.0638	.0800	-20.3				
		1.40	.0573	.0660	-13.2				
5.6	Cranked	0.80	.0799	.0775	3.1				(Tail-Off)
		0.85	.0819	.0820	-0.1				
		0.90	.0839	.0840	-0.1				
		0.92	.0847	.0850	-0.4				
		0.80	.0832	.0810	2.7				(Center Horizontal Position)
		0.85	.0851	.0865	-1.6				
		0.90	.0869	.0880	-1.3				
		0.92	.0877	.0890	-1.5				

TABLE 2-7 (Contd)

Lift Characteristics of Cranked Wing Configurations

Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc	C_{L_α} (deg^{-1}) Test	Percent Error	α_{L_o} -(deg) Calc	α_{L_o} -(deg) Test	Percent Error	Comment
		0.80	.0854	.0830	2.9	0.0	0.0	—	(Mid Horizontal Position)
		0.85	.0873	.0880	-0.8				
		0.90	.0893	.0890	0.3				
		0.92	.0901	.0880	2.4				
5.6	Cranked	0.80	.0871	.0850	2.5				(High Horizontal Position)
		0.85	.0892	.0900	-0.9				
		0.90	.0912	.0910	0.2				
		0.92	.0921	.0920	0.1				
4.7	1(Tail-Off)	.24	.0575	.0684	-15.9	0.0	0.0	-	Outboard Sweep = 25 deg.
	1(Tail-On)		.0675	.0753	-10.4		-0.4		
	1(Tail-Off)		.0405	.0421	-3.8		0.0		Outboard Sweep = 75 deg.
	1(Tail-On)		.0576	.0562	2.5		-0.3		
	2(Tail-Off)		.0607	.0648	-6.3		-0.5		Outboard Sweep = 30 deg.
	2(Tail-On)		.0682	.0760	-10.3		-0.05		
	2 (Tail-Off)		.0383	.035	9.4		-0.8		Outboard Sweep = 70.5 deg.
	2 (Tail-On)		.0536	.051	5.1		-0.8		

2.2.2 PITCHING MOMENT CHARACTERISTICS. The correlation of the pitching moment characteristics are presented in terms of aerodynamic center location, as a fraction of mean aerodynamic chord, and zero lift pitching moment in Tables 2-8 through 2-14. The results indicate the overall prediction accuracy of 15.84 and 45.6 for the straight tapered and cranked wing planforms, respectively, to be poor. These accuracy levels may be attributed to several factors. A major effect is due to the basis utilized in the development of the methodology. The data base utilized to develop the DATCOM methodology was based on the aerodynamic center location (a.c.) expressed as a fraction of the root chord. Since, for most basic configurations the ratio of root chord to the mean aerodynamic chord ranges between 1.5 and 2.5, it is logical that the percent error of the a.c. based on $\bar{c}$ will be considerably higher. Table 2-8 is illustrative of this shift in the aerodynamic center location. The configuration presented in Figure 1 of the reference was utilized. The spanwise location of the reference chord is different from the basic mean aerodynamic chord because it has been shifted to fit within the wing planform lines. The test data had to be shifted to the mac in order to compare with the predicted data. It appears that this reference system is utilized by the NASA for all the cranked wing configurations.

The predicted data in the transonic Mach number range may also be effected by the limitation on the force break Mach number. The methodology presented in the DATCOM limits the maximum attainable force break Mach number to 1.0. Most high sweep low thickness ratio wings exhibit values beyond 1.0.

The configurations investigated in this phase of the study, had wings with no camber, incidence, or twist and symmetrical bodies, therefore, the zero lift pitching moments are zero.

2.2.2.1 Straight Tapered Wing Planform Characteristics. The configurations analyzed for the pitching moment characteristics are the same as were utilized for the lift curve slope investigation as outlined in Section 2.2.1.1.

The results presented in Table 2-9 cover a wide range of planform parameters summarized below

$$2.0 \le A \le 5.9$$

$$0.0 \le \lambda \le 0.474$$

$$0.0 \le \Lambda_{LE} \le 63.4°$$

The overall accuracy level is 15.98 percent which is beyond an acceptable level. However, if the data for the configuration of Reference 3.6 is omitted, the average percent error is 8.84.

The configuration of Reference 3.6 has the engines located in the wing-body intersection which complicates the decision as what to input for the wing and body. This large discontinuity in the wing may account for the test a.c. being so far forward.

The user has to make judgements on how to handle configuration that are not straightforward. These judgements are based on experience and will be fortified as the user has more exposure to the utilization of the Flying Qualities Program.

Table 2-10 presents the results of an investigation to evaluate the effects of wing sweep, taper ratio and horizontal tail position on the pitching moment characteristics. The average percent error is 10 percent with the maximum error ranging from +54.4 to -26.2. The results do not indicate any specific trends with the variables investigated as the percent errors are random.

The effects of variations in body shape and empennage arrangements on the aerodynamic center location are summarized in Table 2-11. The average error is 14.2 percent with the maximum ranging from +27.0 to -13. The T-tail and H-tail empennage arrangements appear to be more predictable than the conventional tail. The tail-off characteristics correlations are not as good as when the empennage is added. It may be concluded from the results that a more comprehensive study needs to be conducted to evaluate variation in empennage arrangement.

The results presented in Tables 2-12 and 2-13 for a highly tapered and swept wing configuration, respectively, show poor correlation between predicted and test data. The results are indicative of the trends found throughout the study. These two configurations are relatively simple wing-body-tail arrangements and would appear to be tailor made for methodology correlation. The results indicate that a systematic study needs to be undertaken to develop a more complete data base and an in-depth analysis performed to provide guidance in modifying the present methodology.

2.2.2.2 <u>Cranked Wing Planform Characteristics</u>. A comparison of experimental data and predicted data of several cranked wing configurations is presented in Table 2-14. The average percent error of 22.8 indicates the same poor correlation as was experienced with straight tapered wings. The methodology was developed utilizing a relatively small data base which limits the suggested accuracy to a small number of configurations. It is suggested that a study be conducted to extend the data base and a review of the methodology be undertaken.

TABLE 2-8

Effect of Reference Chord on Aerodynamic Center Correlation

Test Data From NASA TN D-435

Reference 4.2

	TEST DATA				PREDICTED DATA			
Mach Number	$C_{m_{C_L}}$	$\frac{X_{ac}}{c_{ref}}$	$\frac{X_{ac}}{c_r}$	$\frac{X_{ac}}{\bar{c}_W}$	$\frac{X_{ac}}{\bar{c}_W}$	$\frac{X_{ac}}{c_r}$	Percent Error [1]	Percent Error [2]
0.60	-.319	.569	.816	.485	.420	.777	-13.4	-4.7
0.80	-.324	.574	.819	.490	.433	.785	-11.6	-4.2
0.90	-.330	.580	.822	.495	.443	.791	-12.5	3.8
0.95	-.336	.586	.826	.502	.478	.812	-4.8	-1.7
1.00	-.362	.612	.841	.527	.512	.832	-2.8	-1.1
1.05	-.368	.618	.845	.534	.547	.853	2.4	0.9
1.10	-.380	.630	.852	.546	.582	.874	6.6	2.6
1.17	-.384	.634	.855	.551	.582	.874	5.6	2.2
1.41	-.428	.678	.881	.594	.475	.810	-20.0	-8.1
2.01	-.380	.630	.852	.546	.491	.819	-10.0	-3.8

(1) Based on mean aerodynamic chord

(2) Based on root chord

TABLE 2-9

Pitching Moment Characteristics of Straight Tapered Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$		Percent Error	C_{m_o}		Percent Error	Comment
			Calc	Test		Calc	Test		
6.1	Basic	1.61	.683	.560	21.9	0.0	-.012	-	Vertical Tail Effect is Insignificant
		2.01	.704	.517	36.2				
3.29	WB	.13	.39	.401	-2.7		.008		
	WBV		.39	.401	-2.7				
	WBHV		.56	.501	11.8		0.0		
3.21	W1+F1	0.17	.391	.352	11.1		0.0		
	+F2		.393		11.6				
	+F3		.381		8.2				
	W2+F1		.391	.369	5.9		.005		
	+F2		.393		6.5				
	F3		.381	.384	-.78		.010		
	W3+F1		.393	.350	12.3		0.0		
	+F2		.391		11.7				
	F3		.381		8.9		.005		
3.35	WBV	0.25	.378	.372	1.6		-.007		
		0.60	.387	.394	0.8		-.010		
		0.85	.433	.408	6.1				
		0.92	.457	.430	6.3				
		0.94	.466	.470	-0.9				
3.36	WF	0.17	.235	.110	113.6		-.02		
	WFHV		.499	.324	54.0		+.04		

TABLE 2-10

Pitching Moment Characteristics of Straight Tapered Wing Configurations
Substantiation Data

Ref.	Config. •	M	$X_{ac}/\bar{c}_W$		Percent Error	$^{\bullet}C_{m_o}$		Percent Error	Comment
			Calc	Test		Calc	Test		
4.1	45	0.60	.289	.275	5.1	0.0	0.0	—	(Tail-Off)
		0.80	.332	.282	17.7				
		0.90	.360	.390	24.1				
		1.02	.413	.432	-4.4				
		1.20	.431	.455	-5.3				
		1.40	.423	.483	-12.4				
	53	0.60	.332	.308	7.8				
		0.80	.352	.310	13.5				
		0.90	.386	.336	14.9				
		1.02	.422	.430	-1.9				
		1.20	.439	.475	-7.5				
		1.40	.457	.505	-9.5				
	53 + Tail	0.60	.398	.400	-0.5				(Tail-On)
		0.80	.400	.410	-2.4				
		0.90	.424	.410	3.4				
		1.02	.451	.540	-16.5				
		1.20	.520	.680	-26.2				
		1.40	.579	.720	-19.6				
5.6	Swept	0.80	.364	.320	13.8				(Tail-Off)
		0.85	.380	.327	16.2				
		0.90	.415	.348	19.3				
		0.92	.429	.355	20.8				
		0.80	.450	.431	4.4				(Center Horizontal Position)
		0.85	.459	.438	4.8				
		0.90	.487	.446	9.2				
		0.92	.499	.440	13.4				

TABLE 2-10 (Contd)

Pitching Moment Characteristics of Straight Tapered Wing Configurations

Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$ Calc	$X_{ac}/\bar{c}_W$ Test	Percent Error	C_{m_o} Calc	C_{m_o} Test	Percent Error	Comment
		0.80	.513	.483	6.2	0.0	0.0	—	(Mid Horizontal Position)
		0.85	.522	.490	6.5				
		0.90	.549	.492	11.6				
		0.92	.560	.528	6.1				
5.6	Swept	0.80	.556	.542	2.6				(High Horizontal Position)
		0.85	.566	.550	2.9				
		0.90	.594	.556	6.8				
		0.92	.605	.558	8.4				
3.14	Sweep(19.1)	0.60	.218	.245	-11.0				(Tail-Off)
		0.90	.247	.160	54.4				
		1.02	.321	.300	7.0				
		1.20	.402	.390	3.1				
		1.40	.458	.415	10.4				
	Sweep (45)	0.60	.289	.250	15.6				
		0.90	.333	.275	21.0				
		1.02	.404	.395	2.3				
		1.20	.426	.425	0.24				
		1.40	.429	.460	-6.74				
	Sweep (53.1) Taper (0.4)	0.60	.329	.265	24.2				
		0.90	.359	.295	21.7				
		1.02	.417	.380	9.7				
		1.20	.438	.410	6.8				
		1.40	.461	.455	1.3				
	Taper (0.0) Sweep(53.1)	0.60	.386	.360	7.2				
		0.90	.451	.400	12.8				
		1.02	.498	.480	3.8				

TABLE 2-10 (Contd)

Pitching Moment Characteristics of Straight Tapered Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$		Percent	C_{m_o}		Percent	Comment
			Calc	Test	Error	Calc	Test	Error	
		1.20	.505	.490	3.1	0.0	0.0	—	(Tail-Off)
		1.40	.497	.500	-0.6				
	Taper (0.2) Sweep(53.1)	0.60	.367	.340	7.9				
		0.90	.398	.360	10.6				
		1.02	.469	.480	-2.3				
		1.20	.479	.480	-0.2				
		1.40	.489	.500	-2.2				

TABLE 2-11

Pitching Moment Characteristics of Straight Tapered Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$ Calc	$X_{ac}/\bar{c}_W$ Test	Percent Error	C_{m_o} Calc	C_{m_o} Test	Percent Error	Comment
5.9	Tail-Off	0.6	.328	.285	15.1	0.0	0	-	Tapered Body (Tail-Off)
		0.8	.352	.290	21.4				
		0.9	.403	.293	37.1				
		0.94	.418	.360	16.0				
	Tail 1	0.6	.556	.530	4.9		.003		(T-Tail)
		0.8	.555	.508	9.2		.005		
		0.9	.597	.495	20.6		0		
		0.94	.611	-	-				
	Tail 2	0.6	.442	.406	8.9		0		
		0.8	.439	.393	11.1		-.003		(Conventional Tail)
		0.9	.476	.390	22.1		-.010		
		0.94	.488	.475	2.7		-.015		
	Tail 3	0.6	.442	.412	7.3		0		(Equal Semispans)
		0.8	.439	.375	17.1		.002		
		0.9	.476	.365	30.4		.005		
		0.94	.488	.505	-12.1		.020		
	Tail 3	0.6	.434	.412	5.3		-.010		Cylindrical Body
		0.8	.433	385	12.5		-.007		
		0.9	.471	.385	22.3		-.010		
		0.94	.482	.535	-9.9		+.010		
	Tail 4	0.6	.442	.390	13.3		+.010		Tapered Body (+-Tail)
		0.8	.439	.395	11.1		+.011		
		0.9	.476	.375	26.9		+.010		
		0.94	.488	-	-				
	Tail 5	0.6	.466	.492	-5.2		-.007		
		0.8	.457	.492	-7.1		0		(H-Tail)
		0.9	.491	.460	-6.3		-.009		
		0.94	.501	.580	-13.0		+.010		

TABLE 2-12

Pitching Moment Characteristics of Highly Tapered Wing Configurations Substantiation Data

Ref.	Config.	M	$x_{ac}/\bar{c}_W$		Percent	C_{m_o}		Percent	Comment
			Calc	Test	Error	Calc	Test	Error	
5.2	WFO	0.60	0.223	0.230	-3.0	0	0.0	0	F0, F1, and F2 Form A Nose Length Series
		0.80	0.267	0.234	14.1		0.0	0	
		0.85	0.278	0.214	29.9		0.001	100	
		0.90	0.301	0.215	40.0		0.005	100	
		0.92	0.314	0.226	38.9		0.005	100	
	WF0VH	0.60	0.426	0.408	4.4		0.013	100	
		0.80	0.457	0.415	10.1		0.018	100	
		0.85	0.464	0.407	14.0		0.019	100	
		0.90	0.483	0.400	20.8		0.021	100	
		0.92	0.494	0.408	21.1		0.021	100	
	WF1	0.60	0.204	0.185	10.3		0.0	0	
		0.80	0.250	0.196	27.6		0.0	0	
		0.85	0.261	0.205	27.3		0.003	100	
		0.90	0.283	0.190	49.0		0.001	100	
		0.92	0.297	0.210	41.4		0.005	100	
	WF1VH	0.60	0.409	0.382	7.1		0.013	100	
		0.80	0.441	0.405	8.9		0.017	100	
		0.85	0.449	0.397	13.1		0.020	100	
		0.90	0.469	0.393	19.3		0.022	100	
		0.92	0.479	0.400	19.8		0.023	100	
	WF2	0.60	0.193	0.170	13.3		0.002	100	
		0.80	0.239	0.187	27.8		0.0	0	
		0.85	0.250	0.190	31.6		-0.1	-100	
		0.90	0.273	0.190	43.7		0.001	100	
		0.92	0.287	0.203	41.4		0.002	100	

TABLE 2-12 (Contd)

Pitching Moment Characteristics of Highly Tapered Wing Configuration
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$ Calc	$X_{ac}/\bar{c}_W$ Test	Percent Error	C_{m_o} Calc	C_{m_o} Test	Percent Error	Comment
5.2	WF2VH	0.60	0.399	0.350	14.0	0	0.015	100	F0, F1, and F2 Form A Nose Length Series
		0.80	0.431	0.370	16.5		0.017	100	
		0.85	0.439	0.376	16.7		0.021	100	
		0.90	0.458	0.372	23.1		0.022	100	
		0.92	0.470	0.375	25.3		0.022	100	
	WF3	0.60	0.242	0.230	5.2		0.002	100	
		0.80	0.285	0.234	21.8		0.0	0	
		0.85	0.296	0.234	26.5		0.005	100	
		0.90	0.318	0.239	33.1		0.004	100	
		0.92	0.332	0.254	30.7		0.005	100	
	WF3VH	0.60	0.442	0.436	1.4		0.013	100	
		0.80	0.472	0.425	11.1		0.017	100	
		0.85	0.480	0.415	15.7		0.019	100	
		0.90	0.498	0.415	20.0		0.021	100	
		0.92	0.510	0.428	19.2		0.019	100	
	WF4	0.60	0.181	0.140	29.3		0.003	100	F4, F2, and F1 Form A Nose-Fineness-Ratio Series
		0.80	0.228	0.164	39.0		0.000	100	
		0.85	0.240	0.163	47.2		0.003	100	
		0.90	0.263	0.160	64.4		0.003	100	
		0.92	0.276	0.168	64.3		0.002	100	
	WF4VH	0.60	0.389	0.335	16.1		0.013	100	
		0.80	0.422	0.359	17.5		0.015	100	
		0.85	0.430	0.343	25.4		0.018	100	
		0.90	0.449	0.343	30.9		0.022	100	
		0.92	0.460	0.340	35.3		0.022	100	

TABLE 2-12 (Contd)

Pitching Moment Characteristics of Highly Tapered Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$ Calc	$X_{ac}/\bar{c}_W$ Test	Percent Error	C_{m_o} Calc	C_{m_o} Test	Percent Error	Comment
5.2	WF5	0.60	0.212	0.188	12.8	0	0.003	100	F4, F2, and F1 Form A Nose-Fineness-Ratio Series
		0.80	0.257	0.203	11.7		0.000	0	
		0.85	0.268	0.204	31.4		-.002	-100	
		0.90	0.290	0.195	48.7		0.002	100	
		0.92	0.304	0.220	38.2		0.002	100	
	WF5VH	0.60	0.416	0.372	11.8		0.014	100	
		0.80	0.447	0.390	14.6		0.015	100	
		0.85	0.445	0.372	19.6		0.018	140	
		0.92	0.485	0.377	23.6		0.019	100	

TABLE 2-13

Pitching Moment Characteristics of Swept Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$ Calc	$X_{ac}/\bar{c}_W$ Test	Percent Error	C_{m_o} Calc	C_{m_o} Test	Percent Error	Comment
5.2	WF0	0.80	0.354	0.318	11.3	0	0.001	100	F0, F1, and F3 Form A Nose Length Series
		0.85	0.370	-	-		-	-	
		0.90	0.405	0.328	23.5		0.002	100	
		0.92	0.418	-	-		-	-	
	WF0VH	0.80	0.459	0.430	6.7		-0.004	-100	
		0.85	0.467	0.430	8.6		-0.005	-100	
		0.90	0.492	0.435	13.1		-0.006	-100	
		0.92	0.503	0.445	13.0		-0.006	-100	
	WF1	0.80	0.338	0.300	12.7		-0.002	-100	
		0.85	0.355	-	-		-	-	
		0.90	0.389	0.315	23.5		-0.002	-100	
		0.92	0.403	-	-		-	-	
	WF1VH	0.80	0.445	0.415	7.2		-.010	-100	
		0.85	0.452	0.415	8.9		-.011	-100	
		0.90	0.478	0.417	14.6		-.012	-100	
		0.92	0.488	0.429	13.8		-.013	-100	
	WF2	0.80	0.329	0.290	13.4		-0.003	-100	
		0.85	0.345	-	-		-	-	
		0.90	0.380	0.318	19.5		-0.003	-100	
		0.92	0.394	-	-		-	-	
	WF2VH	0.80	0.436	0.420	3.8		-.011	-100	
		0.85	0.443	0.420	5.5		-.011	-100	
		0.90	0.469	0.425	10.4		-.011	-100	
		0.92	0.479	0.430	11.4		-.011	-100	

TABLE 2-13 (Contd)

Pitching Moment Characteristics of Swept Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$		Percent	C_{m_o}		Percent	Comment
			Calc	Test	Error	Calc	Test	Error	
5.2	WF3	0.80	0.369	0.331	11.5	0	-0.002	-100	F3, F4, and F5 Form A Fuselage Length Series
		0.85	0.385	-	-		-	-	
		0.90	0.420	0.345	21.7		0	0	
		0.92	0.434	-	-		-	-	
	WF3VH	0.80	0.474	0.453	4.6		--.010	-100	
		0.85	0.482	0.453	6.4		-.011	-100	
		0.90	0.507	0.446	13.7		-.012	-100	
		0.92	0.517	0.460	12.4		-.014	-100	
	WF4	0.80	0.320	0.267	19.9		0.001	100	F4, F2, and F1 Form A Nose-Fineness-Ratio Series
		0.85	0.336	-	-		-	-	
		0.90	0.371	0.294	26.2		0.003	100	
		0.92	0.385	-	-		-	-	
	WF4WB	0.80	0.428	0.345	8.4		-.010	-100	
		0.85	0.435	0.395	10.1		-.010	-100	
		0.90	0.460	0.409	12.5		-.011	-100	
		0.92	0.470	0.413	13.8		-.012	-100	
	WF5	0.80	0.345	0.301	14.6		-0.001	100	
		0.85	0.361	-	-		-	-	
		0.90	0.395	0.316	25.0		-.001	-100	
		0.92	0.409	-	-		-	-	
	WF5WB	0.80	0.451	0.440	2.5		-.010	-100	
		0.85	0.458	0.440	4.1		-.011	-100	
		0.90	0.484	0.440	10.0		-.012	-100	
		0.92	0.494	0.460	7.4		-.013	-100	

TABLE 2-14

Pitching Moment Characteristics of Cranked Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$ Calc	$X_{ac}/\bar{c}_W$ Test	Percent Error	* C_{m_0} Calc	* C_{m_0} Test	Percent Error	Comment
4.1	53-32	0.60	.436	.282	54.6	0.0	0.0	—	(Tail-Off)
		0.80	.432	.285	51.6				
		0.90	.428	.306	39.9				
		1.02	.495	.422	17.3				
		1.20	.578	.468	23.5				
		1.40	[illegible]	.482	5.19				
	53-43	0.60	.372	.300	24.0				
		0.80	.373	.310	20.3				
		0.90	.368	.321	14.6				
		1.02	.443	.440	0.7				
		1.20	.508	.490	3.7				
		1.40	.434	.505	-14.1				
	53-32+Tail	0.60	.487	.363	34.2				
		0.80	.480	.350	37.1				
		0.90	.473	.340	39.1				
		1.02	.536	.510	5.1				
		1.20	.648	.680	-4.7				
		1.40	.618	.700	-11.7				
5.6	Cranked	0.80	.424	.261	62.5				(Tail-Off)
		0.85	.425	.272	56.3				
		0.90	.426	.358	18.9				
		0.92	.432	.374	15.5				
		0.80	.511	.381	34.1				(Center Horizontal Position)
		0.85	.507	.360	40.8				
		0.90	.503	.408	23.3				
		0.92	.506	.475	6.5				

TABLE 2-14 (Contd)
Pitching Moment Characteristics of Cranked Wing Configurations
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$		Percent	C_{m_o}		Percent	Comment
			Calc	Test	Error	Calc	Test	Error	
		0.80	.559	.414	35.0	0.0	0.0		(Mid Horizontal Position)
		0.85	.556	.412	34.9				
		0.90	.552	.456	21.1				
		0.92	.556	.505	10.1				
5.6	Cranked	0.80	.598	.474	26.2				(High Horizontal Position)
		0.85	.596	.474	25.7				
		0.90	.593	.520	14.0				
		0.92	.598	.545	9.7				
4.7	1 (Tail-Off)	0.24	.434	.423	2.5	0.0	.005	-	Outboard Sweep = 25 deg
	1 (Tail-On)		.615	.522	17.8		.0025		
	1 (Tail-Off)		.272	.311	-12.5		.0025		Outboard Sweep = 75 deg.
	1 (Tail-On)		.640	.493	29.8		.0025		
	2 (Tail-Off)		.362	.389	-6.9		.0025		Outboard Sweep = 30 deg.
	2 (Tail-On)		.517	.480	7.7		.0025		
	2 (Tail-Off)		.318	.359	-11.4		.005		Outboard Sweep = 70.5 deg.
	2 (Tail-On)		.627	.471	33.0		-.005		

2.2.3 SIDESLIP CHARACTERISTICS. An investigation has been conducted to determine the effects of vertical location of the wing and horizontal tail, vertical tail size, fuselage fineness ratio and empennage arrangement on the sideslip characteristics. The results are presented in Tables 2-15 through 2-18 and show poor correlation between the estimated and test data for the yawing and rolling moment. The accuracy levels of the sideforce characteristics are marginal if some data points are eliminated.

The results of these studies indicate that the present methodology is very sensitive to changes in configuration. A cursory evaluation indicates the large percentage errors result from several sources, such as, extracting data from the NASA reports, matching test conditions, tail arms due to a.c. prediction techniques (Section 2.2.2), body side area, supersonic apparent mass factor, and force break Mach number. A complete discussion of these items may be found in Section 2.3.

2.2.3.1 Straight Tapered Wing Planform Characteristics. Table 2-15 presents the results of an investigation to evaluate the effect of vertical tail size and fuselage fineness ratio on the aerodynamic characteristics in sideslip. The sideforce characteristics correlations are good except for the configurations of References 3.6, 3.29, and 3.35. The average percent error excluding these configurations is 8.2.

The yawing moment due to sideslip correlations show poor correlation for most of the configurations evaluated in this series. The tail-off results for the configurations of References 6.1 and 3.35 and the body fineness ratio and tail size studies of Reference 3.21 are the only results that have average percent errors less than 15 percent.

Table 2-16 presents the effects of the vertical location of the wing and horizontal tail on the sideslip characteristics of a swept wing configuration. The same trends are observed for this set of data as for the previous data. The average percent error for the sideforce, yawing moment and rolling moment is 21.3, 41.4 and 25.7, respectively.

The results of Table 2-17 show correlations of various empennage arrangements. The results show average errors of the same magnitude as previously discussed.

2.2.3.2 Cranked Wing Planform Characteristics. A comparison of experimental data and data estimated utilizing the Flying Qualities Program for tail-off and tail-on sideslip characteristics of a cranked wing configuration is presented in Table 2-18. The results show the same trends as observed for the straight tapered wing investigation. The accuracy levels are 19.7, 67.0 and 17.4 for the sideforce, yawing moment and rolling moment, respectively.

TABLE 2-15

Lateral-Directional Characteristics of Straight Tapered Wing Configurations
Substantiation Data - $\alpha = 0.0°$

Ref.	Config	M	C_{Y_β} (rad^{-1}) Calc	C_{Y_β} (rad^{-1}) Test	Percent Error	C_{n_β} (rad^{-1}) Calc	C_{n_β} (rad^{-1}) Test	Percent Error	C_{ℓ_β} (rad^{-1}) Calc	C_{ℓ_β} (rad^{-1}) Test	Percent Error	Comment
6.1	Tail-Off	1.41	-.264	-.264	0.0	-.082	-.086	-4.7	.0318	.0676	-52.9	
		1.61		-.258	-2.3	-.081	-.095	-14.7		.0458	-30.6	
		2.01		-.258	-2.3	-.079	-.092	-14.1		.0458	-30.6	
	Basic	1.41	-.727	-.733	-.8	.107	.100	7.6	-.0277	-.0097		
	Tail	1.61	-.681	-.630	8.1	.091	.066	37.9	-.0218	-.0029		
		2.01	-.585	-.516	13.4	.054	.032	68.9	-.0093	+.022		
	Extended	1.61	-.757	-.653	15.9	.130	.0791	64.3	-.0349	-.0086		
	Tail											
	127%	1.41	-.857	-.745	15.0	.168	.115	46.1	-.0489	-.0315	55.2	
	Tail	1.61	-.791	-.676	17.0	.142	.085	67.1	-.0400	-.0160	-	
3.29	WB	.13	-.101	-.057	77.2	-.052	-.069	-24.6	0.0	-0.012	-	
	WBV		-.696	-.458	51.9	.326	.183	78.1	-.069	-.074	-6.7	
	WBHV		-.696	-.516	34.9	.326	.229	42.4	-.069	-.052	32.7	
3.21	W1+F1	0.17	-.055	-.057	-3.5	-.026	-.029	-10.3	0.0	0.0	-	
	+F2		-.098	-.103	-4.9	-.048	-.057	-15.8				
	+F3		-.221	-.183	20.8	-.101	-.126	-19.8				
	W1+F1+V1		-.279	-.286	-2.4	.107	.103	3.9	-.018	-.0229	-21.4	
	+F2+V2		-.394	-.407	-3.2	.126	.115	9.6	-.029	-.034	-14.7	
	+F1+V3		-.407	-.418	-2.6	.185	.179	3.9	-.032	-.046	-30.4	
	+F2+V3		-.506	-.481	5.2	.194	.172	12.8	-.043	-.052	-17.3	
	+F3+V3		-.676	-.630	7.3	.164	.126	30.2	-.060	-.069	-13.0	

TABLE 2-15 (Contd)

Lateral-Directional Characteristics of Straight Tapered Wing Configurations
Substantiation Data - α - 0.0°

Ref.	Config	M	C_{Y_β} (rad^{-1}) Calc	C_{Y_β} (rad^{-1}) Test	Percent Error	C_{n_β} (rad^{-1}) Calc	C_{n_β} (rad^{-1}) Test	Percent Error	C_{ℓ_β} (rad^{-1}) Calc	C_{ℓ_β} (rad^{-1}) Test	Percent Error	Comment
3.35	WBV	0.25	-.472	-.528	-10.6	.0083	.0509	-83.7	-.0335	-.0069	385.6	Flaps Up
		0.60	-.486	-.516	-5.8	.0190	.0544	-65.1	-.0351	-.0057	515.8	
		0.85	-.548	-.579	-5.4	.0385	.063	-38.9	-.0412	0.0	-	
		0.92	-.566	-.584	-3.1	.0466	.0556	-16.2	-.0429	.0229	287.3	
		0.94	-.571	-.493	15.8	.0499	.0441	13.2	-.0435	.0057	863.2	
	WB	0.25	-.1194	-.069	73.0	-.0777	-.0602	29.1	.0111	.0160	-30.6	
		0.60	-.1194	-.057	109.5	-.0716	-.0644	11.2		.0160	-30.6	
		0.85	-.1344	-.069	94.8	-.0712	-.0711	.14		.0275	-59.6	
		0.92	-.1385	-.069	100.7	-.0716	-.0751	-4.7		.0229	-51.5	
		0.94	-.1397	-.069	102.5	-.0713	-.0733	-2.7		.0344	-67.7	
3.6	Tail-On	.17	-.894	-1.35	-33.8	.195	.260	-25.0	-.125	-.14	-10.7	Landing Configuration
	Tail-Off		-.24	-.70	-65.7	-.148	-.196	-24.5	-.102	-.09	13.3	
3.36	WF	0.17	-.168	-.232	-27.6	-.0277	-.0229	20.9	.068	-.014	585.7	
	WFHV		-.627	-.602	4.2	.1565	.1146	36.6	.037	-.057	164.9	

TABLE 2-16

Lateral-Directional Characteristics of Straight Tapered Wing Configuration

Substantiation Data - $\alpha = 0$

Ref.	Config	M	C_{Y_β} (rad^{-1}) Calc	C_{Y_β} (rad^{-1}) Test	Percent Error	C_{n_β} (rad^{-1}) Calc	C_{n_β} (rad^{-1}) Test	Percent Error	C_{ℓ_β} (rad^{-1}) Calc	C_{ℓ_β} (rad^{-1}) Test	Percent Error	Comment
5.6	Swept	0.80	-.1333	-.1146	16.3	-.1555	-.0974	60.2	0	-.0057	-	(Tail-Off)
		0.85	-.1364		19.0	-.1561		60.2			-	
		0.90	-.1394		21.6	-.1569		61.2			-	
		0.92	-.1406		22.7	-.1573		61.2			-	
		0.80	-.8702	-.7334	18.6	.1629	.1730	-5.8	-.0843	-.0602	40.0	(Center Tail)
		0.85	-.8493		15.8	.1553	.1730	-10.4	-.0816	-.0619	32.3	
		0.90	-.8282		12.9	.1474	.1776	-17.4	-.0788	-.0630	25.4	
		0.92	-.8198		11.8	.1442	.1776	-19.1	-.0777	-.0630	23.8	
		0.80	-.9514	-.928	2.5	.2408	.2549	-5.5	-.0936	-.1478	-36.5	(High Tail)
		0.85	-.9217		-0.7	.2119	.2865	-26.1	-.0899	-.1536	-41.6	
		0.90	-.8920		-3.9	.1841	.2979	-38.3	-.0861	-.1604	-46.3	
		0.92	-.8801		-5.2	.1732	.2922	-40.8	-.0846	-.1489	-42.9	
5.8	Swept Low Wing	2.01	-.306	-.327	-6.3	-.100	-.092	8.7	.0390	.0573	-31.9	(Tail-Off)
			-1.26	-.888	41.8	.384	.255	50.6	-.0424	-.0413	2.7	(High Tail 1)
			-1.29	-.888	45.3	.402	.249	61.4	-.0464	-.0429	6.9	(Mid Tail 2)
			-1.26	-1.00	26.0	.382	.252	51.6	-.042	-.0304	38.2	(Low Tail 3)
	Swept Mid Wing		-.217	-.229	-5.2	-.1004	-.0917	8.7	0	0	-	(Tail-Off)
			-1.17	-.899	30.0	.382	.252	51.6	-.81	-.079	2.5	(High Tail 1)
			-1.19	-.671	36.6	.399	.246	62.2	-.085	-.0728	16.8	(Mid Tail 2)
			-1.16	-.860	34.9	.380	.252	50.8	-.080	-.0670	19.4	(Low Tail 3)
	Swept High Wing		-.372	-.344	-7.5	-.1004	-.1089	-8.3	-.0390	-.0573	-31.9	(Tail-Off)
			-1.32	-.957	37.9	.382	.228	67.5	-.1200	-.1375	-12.7	(High Tail 1)
			-1.35	-.888	52.0	.400	.223	79.4	-.102	-.123	-17.1	(Mid Tail 2)
			-1.32	-.974	35.5	.380	.203	87.2	-.120	-.100	20.0	(Low Tail 3)

TABLE 2-17

Lateral-Directional Characteristics of Straight Tapered Wing Configurations
Substantiation Data - $\alpha = 0.0°$

Ref.	Config	M	C_{Y_β} (rad^{-1}) Calc	C_{Y_β} (rad^{-1}) Test	Percent Error	C_{n_β} (rad^{-1}) Calc	C_{n_β} (rad^{-1}) Test	Percent Error	C_{ℓ_β} (rad^{-1}) Calc	C_{ℓ_β} (rad^{-1}) Test	Percent Error	Comment
5.9	Tail-Off	0.6	-.121	-.086	40.7	-.091	-.089	2.2	0.0	0.0	-	Tapered Body
		0.8	-.133	-.086	54.7	-.095	-.092	3.3				
		0.9	-.139	-.089	56.2	-.097	-.095	2.1				
		0.94	-.142	-.120	18.3	-.097	-.115	-15.7				
	Tail 1 (T-Tail)	0.6	-.767	-.859	-10.8	.237	.287	-17.4	-.071	0.0	-	
		0.8	-.843	-1.003	-15.9	.262	.355	-26.2	-.078			
		0.9	-.867	-.831	4.3	.272	.264	3.0	-.080			
		0.94	-.829	-.916	-9.5	.256	.269	-4.8	-.076			
	Tail 2 (Conventional Tail)	0.6	-.618	-.647	-4.5	.161	.181	-11.0	-.056	-.052	7.7	
		0.8	-.656	-.668	-1.8	.168	.189	-11.1	-.058	-.052	11.5	
		0.9	-.675	-.693	-2.6	.175	.201	-12.9	-.059	-.057	3.5	
		0.94	-.683	-.630	8.4	.181	.155	-16.8	-.060	-.057	5.3	
	Tail 3 (Equal Semispans)	0.6	-.378	-.412	-8.2	.037	.069	-46.4	-.023	-.017	+35.3	
		0.8	-.374	-.418	-10.5	.025	.063	-60.3	-.022	-.017	29.4	
		0.9	-.373	-.401	-7.0	.023	.060	-61.7	-.021	-.017	23.5	
		0.94	-.372	-.401	-7.2	.023	.040	-42.5	-.021	-.017	23.5	
	Tail 3 (Equal Semispans)	0.6	-.370	-.453	-17.0	.028	.092	-69.6	-.026	-.017	52.9	Cylindrical Body
		0.8	-.362	-.487	-25.7	.011	.095	-88.4	-.023	-.017	35.3	
		0.9	-.355	-.487	-27.1	.003	.097	-96.9	-.022	-.017	29.4	
		0.94	-.353	-.493	-28.4	0.0	.097	-	-.022	-.017	29.4	
	Tail 4 (+-Tail)	0.6	-.498	-.756	-34.1	.098	.241	-59.3	-.012	0.0	-	Tapered Body
		0.8	-.565	-.788	-28.3	.123	.241	-48.9	-.005			
		0.9	-.598	-.751	-20.4	.134	.229	-41.5	0.0	0.0		
		0.94	-.611	-.745	-18.0	.142	.183	-22.4	0.0			
	Tail 5 (H-Tail)	0.6	-.351	-.384	-8.6	.025	.057	-56.1	-.022			
		0.8	-.363	-.384	-5.5	.020	.052	-61.5	-.022			
		0.9	-.369	-.390	-5.4	.017	.052	-67.3	-.022			
		0.94	-.371	-.386	-3.9	.018	.046	-60.9	-.022			

TABLE 2-18

Lateral-Directional Characteristics of Cranked Wing Configurations
Substantiation Data

Ref.	Config	M	C_{Y_β} (rad^{-1}) Calc	Test	Percent Error	C_{n_β} (rad^{-1}) Calc	Test	Percent Error	C_{ℓ_β} (rad^{-1}) Calc	Test	Percent Error	Comment
4.7	1(Tail-Off)	0.24	-.193	-.154	25.3	-.0115	-.067	-82.8	-.023	-.0410	-43.9	Outboard
	1(Tail-On)		-.579	-.503	15.1	.103	.067	53.7	-.049	-.0517	-5.2	Sweep = 25 deg.
	1(Tail-Off)		-.225	-.201	11.9	-.023	-.129	-82.2	-.042	-.025	6.8	Outboard
			-.717	-.541	32.5	.228	.136	67.6	-.099	-.093	6.5	Sweep = 75 deg.
	2(Tail-On)		-.652	-.573	13.8	.213	.143	48.9	-.096	-.077	24.7	Outboard Sweep = 70.5 deg.

2.2.4 DYNAMIC STABILITY CHARACTERISTICS. The available methodologies for the dynamic stability characteristics are derived from theoretical analysis. The DATCOM does not present any substantiation of the methods which raises some questions as to its creditability.

Because of the limited amount of test data that systematically varied the configuration parameters, the large number of derivatives, and the compressed time schedule, only a few configurations were evaluated. It is imperative that much more analysis be conducted to develop a data base for each of the dynamic derivatives that will allow for some rational decision to be made as to the validity of the methodology.

2.2.4.1 Longitudinal Dynamic Characteristics. The longitudinal dynamic characteristics correlation data are presented in Table 2-19 for three configurations and a comparison with a sample problem from the DATCOM is presented in Table 2-20. The results show reasonable correlation for the configuration from Reference 3.35 except at the high transonic Mach numbers. The results for the configurations presented in Reference 3.40 show poor correlation. No data was available for C_{Z_q}.

To check the coding for the longitudinal dynamic derivatives the sample problem presented in the DATCOM was run and the comparison of the FQP program results to the DATCOM values are presented in Table 2-20. The reason for the differences are discussed below.

The wing-body derivative difference is due to the section lift curve slope and body lift curve slope. The section lift curve slope used in the DATCOM sample was not a function of the Reynolds number and Mach number stated in the example. The Flying Qualities Program utilizes a body lift curve slope of (2) and (2.8) for the subsonic and supersonic speeds respectively while the sample problem used the methods of DATCOM Section 4.2.1.1 and obtained a value of 1.89 and 2.74.

The tail contribution differs due to the tail body interference terms, exposed tail area and the dynamic pressure ratio at the tail. Since the horizontal tail is off the body, the FQP assumes the exposed area is equal to the theoretical area and that the tail body interference is negligible. The methodology for the dynamic pressure ratio at the tail states that for $Z/Z_W \geq 1.0$ the dynamic pressure ratio $q/q_\infty = 1.0$. The sample problem shows $Z/Z_W > 1.0$ and a $q/q_\infty = 0.901$, which does not agree with the stated methodology.

2.2.4.2 Lateral-Directional Dynamic Characteristics. The correlation studies for the lateral-directional dynamic characteristics were limited to a few configurations due to the limited amount of applicable test data. The results of the correlation studies conducted for the rolling and yawing moment characteristics are presented in Tables 2-21 and 2-22, respectively.

Test data on the rolling stability characteristics is hard to find in the literature and its credibility is questionable. Table 2-21 shows the comparison of some and test data for a subsonic to supersonic Mach number range. The results indicate poor correlation for C_{Y_p} and C_{n_p}. The accuracy of the results for C_{ℓ_p} show reasonable values for some configurations and questionable accuracy for others. The methodologies for the rolling stability characteristics are based on an extremely small amount of test data or none at all, which raises some questions as to its credibility. It is suggested that much more analysis will be required to develop an adequate data base necessary to fully evaluate the present methodology.

The yawing stability characteristics correlation results are presented in Table 2-22. The results are similar to the rolling stability analysis and the overall accuracy is poor. The average percent errors for the sideforce, yawing moment (excluding the WB results of Reference 3.35) and rolling moment are 55.7, 36.5, and 57.8, respectively.

TABLE 2-19

Longitudinal Dynamic Characteristics Substantiation Data

Ref.	Config.	M	C_{Z_q} (Rad^{-1})		Percent	$C_{m_q} + C_{m_{\dot{\alpha}}} (rad^{-1})$		Percent	Comment
			Calc	Test	Error	Calc	Test	Error	
3.35	WBV	0.25	-1.87		-	-1.21	-1.22	-.8	Flaps Up
		0.60	-1.96			-1.43	-1.64	-12.8	
		0.85	-2.03			-1.68	-2.07	-18.8	
		0.92	-2.23			-2.36	-2.33	1.3	
		0.94	-2.30			-2.77	0.0	-	
	WB	0.25	-1.87			-1.21	-1.32	-8.3	
		0.60	-1.96			-1.43	-1.70	-15.9	
		0.85	-2.03			-1.68	-2.42	-30.6	
		0.92	-2.23			-2.36	-2.53	-6.7	
		0.94	-2.30			-2.77	-0.77	259.7	
3.40	Triangular Wing	0.60	-1.73			-1.40	-1.10	27.3	
		0.90	-1.72			-1.50	-1.33	12.8	
		0.98	-1.94			-4.50	-2.44	84.4	
		1.00	-1.98			-6.84	-1.90	260.0	
		1.20	-1.94			-1.33	-0.85	56.5	
		1.40	-2.19			-1.03	-0.77	33.8	
		1.60	-1.68			-0.79	-0.68	16.2	
	Straight Wing	0.60	-1.16			-0.32	-0.80	-60.0	
		0.90	-1.24			-2.90	-2.70	7.4	
		0.98	-1.64			-11.53	-3.00	284.3	
		1.00	-1.79			-17.35	-2.90	498.3	
		1.20	-2.58			-2.36	-0.75	214.7	
		1.40	-1.35			0.61	-0.30	-303.3	
		1.60	-1.20			-0.15	-0.40	-62.5	

TABLE 2-20

Longitudinal Dynamic Characteristics Substantiation Data

Ref.	Config.	M	C_{Z_q} (rad^{-1}) Calc	C_{Z_q} (rad^{-1}) DATCOM	Percent Error	C_{m_q} (rad^{-1}) Calc	C_{m_q} (rad^{-1}) DATCOM	Percent Error	Comment
-	WB	0.6	-1.09	-.864	-	-.289	-0.40	-	DATCOM SAMPLE PROBLEM 7.4.4.1 & 7.4.4.2
		1.4	.177	.485		.978	1.31		
	WBT	0.6	-3.23	-2.40		-5.26	-3.88		
		1.4	-0.501	-0.231		-0.65	-0.31		

Ref.	Config.	M	$C_{Z_{\dot{\alpha}}}$ (rad^{-1}) Calc	$C_{Z_{\dot{\alpha}}}$ (rad^{-1}) DATCOM	Percent Error	$C_{m_{\dot{\alpha}}}$ (rad^{-1}) Calc	$C_{m_{\dot{\alpha}}}$ (rad^{-1}) DATCOM	Percent Error	Comment
-	WB	0.6	-4.67	-4.47	-	-5.12	-4.02	-	DATCOM SAMPLE PROBLEM 7.4.1.1 & 7.1.1.2
		1.4	-3.73	-3.98		-4.96	-4.96		
	WBT	0.6	-9.19	-7.47		-15.6	-10.8		
		1.4	-7.36	-6.45		-13.67	-10.5		

TABLE 2-21

Rolling Stability Characteristics Substantiation Data

Ref.	Config	M	C_{Y_p} (rad^{-1}) Calc	C_{Y_p} (rad^{-1}) Test	Percent Error	C_{n_p} (rad^{-1}) Calc	C_{n_p} (rad^{-1}) Test	Percent Error	C_{ℓ_p} (rad^{-1}) Calc	C_{ℓ_p} (rad^{-1}) Test	Percent Error	Comment
3.35	WBV	0.25	.0891	-	-	-.0218	-.002	-	-.193	-.187	3.2	Flaps Up, $\alpha=0°$
		0.60	.0923	↓	↓	-.0229	-.0160	↓	-.195	-.175	11.4	↓
		0.85	.1046			-.0277	0.0		-.197	-.195	1.0	
		0.92	.1080			-.0299	-.003		-.197	-.206	-4.4	
		0.94	.1090			-.0306	-.030		-.198	-.270	-27.7	
	WB	0.25	0.0			0.0	0.0		-.182	-.145	25.5	
		0.60	↓			↓	-.016		-.184	-.155	18.7	
		0.85					-.002		-.184	-.163	12.9	
		0.92					+.010		-.184	-.220	-16.4	
		0.94					-.060		-.184	-.227	-18.9	
3.6	Tail-On	0.17	.463	.300	54.3	-.109	-.058	87.9	-.313	-.30	4.3	Landing Config.
	Tail-Off		.365	.250	46.0	-.085	.050	270.0	-.312	-.30	4.0	$\alpha=8°$
3.36	WF	0.17	0.0	.030	-	0.0	0.0	-	-.427	-.370	15.4	$\alpha=0°$
			.080	.105	-23.8	-.071	-.025	184.	-.430	-.380	13.2	$\alpha=8°$
	WFHV		.061	.050	22.0	-.0245	0.0	-	-.431	-.380	13.2	$\alpha=0°$
			.09	.181	-50.2	-.074	-.045	64.4	-.430	-.390	10.3	$\alpha=8°$
3.38	WF	0.60	0.0	-.04	-	0.0	0.0	-	-.339	-.300	13.0	$\alpha=0°$
		0.85	↓	-.04	↓	↓		↓	-.338	-.310	9.0	↓
		0.92		-.04					-.338	-.325	4.0	
		0.95		-.05					-.338	-.330	2.4	
3.38	WF	0.60	.351	.005		-.085	.035		-.345	-.359	-3.9	$\alpha=6°$
		0.85	.404	-.090		-.103	.045		-.345	-.360	-4.2	
		0.92	.419	-.140		-.108	.050		-.345	-.370	-6.8	
		0.95	.426	-.145		-.109	.040		-.346	-.380	-8.9	

TABLE 2-21 (Contd)

Rolling Stability Characteristics Substantiation Data

Ref.	Config	M	C_{Y_p} (rad^{-1})		Percent Error	C_{n_p} (rad^{-1})		Percent Error	C_{ℓ_p} (rad^{-1})		Percent Error	Comment
			Calc	Test		Calc	Test		Calc	Test		
3.38 (con't)	WFVH	0.60	.119	-.03	-	.051	.002	-	-.353	-.325	8.6	$\alpha=0°$
		0.85	.119	-.025		.052	.003		-.351	-.328	7.0	
		0.92	.120	-.030		.053	.005		-.351	-.340	3.2	
		0.95	.120	-.025		.053	.010		-.351	-.340	3.2	
		0.60	.421	.045		-.115	0.0		-.349	-.360	-3.1	$\alpha=6°$
		0.85	.474	-.025		-.130	.005		-.349	-.370	-5.7	
		0.92	.488	-.045		-.138	.008		-.349	-.392	-10.9	
		0.95	.494	-.065		-.139	.005		-.350	-.400	-12.5	

TABLE 2-22

Yawing Stability Characteristics Substantiation Data

$\alpha = 0°$

Ref.	Config	M	C_{Y_r} (rad^{-1}) Calc	C_{Y_r} (rad^{-1}) Test	Percent Error	C_{n_r} (rad^{-1}) Calc	C_{n_r} (rad^{-1}) Test	Percent Error	C_{ℓ_r} (rad^{-1}) Calc	C_{ℓ_r} (rad^{-1}) Test	Percent Error	Comment
3.35	WBV	0.25	.172			-.161	-.118	36.4	.022	.038	-42.1	Flaps Up, α=0°
		0.60	.181			-.147	-.127	15.7	.023	.052		
		0.85	.219			-.159	-.131	21.4	.028	.053	-47.2	
		0.92	.236			-.167	-.120	39.2	.029	.072	-59.7	
		0.94	.242			-.168	-.075	124.0	.031	.075	-58.7	
	WB	0.25	0.0			-.119	-.025	376.0	0.0	0.0		
		0.60				-.102	-.035	191.4		.005		
		0.85				-.100	-.050	100.0		.012		
		0.92				-.102	-.058	75.9		.028		
		0.94				-.101	-.057	77.2		.108		
3.6	Tail-On	.17	.686	.52	31.9	-.568	-.57	-.35	.134	.15	-10.7	Landing Config.
	Tail-Off		0.0	-.14		-.209	-.15	39.3	.110	.07	57.1	α=8°
3.36	WF	.13	0.0	-.015		-.023	-.040	-42.5	0.0	-.04	-	α=0°
				-.030		-.030	-.045	-33.3	.159	.10	59.0	α=8°
	WBHV		.368	.23	60.0	-.171	-.135	26.7	.025	.01	150.0	α=0°
				.21	75.2	-.178	-.145	22.8	.163	.12	35.8	α=8°

2.2.5 CONTROL EFFECTIVENESS CHARACTERISTICS. The control effectiveness correlation studies included the evaluation of aerodynamic control characteristics of stabilizers, elevators, ailerons, spoilers, differentially deflected horizontal tails, and rudders. The results of the correlation studies are presented in Tables 2-23 through 2-28.

2.2.5.1 Longitudinal Control Effectiveness. The longitudinal control effectiveness substantiation data that have been analyzed are presented in Tables 2-23 and 2-24. The results indicate that the control characteristics are strongly influenced by wing planform and Mach number. The correlations show that the present methodology does not predict the transonic characteristics within an acceptable level for most cases that were investigated.

The large percentage errors for the CV-880 are primarily due to the differences between the predicted and test values for the horizontal tail lift curve slope. Unpublished pressure data shows large negative pressures in the region of the tail lower surface, which differs from the assumed pressure distribution utilized in the methodology development. Therefore, the predicted lift curve slope is higher than the test values. If the test values are utilized in the equations, the correlations are within 10 percent, as shown in Table 2-24. Since this type of data was not available for the other configurations investigated, the reasons for the large errors in some instances are not verified. However, it does point out that before making decisions on the adequacy of the methodology for the various derivatives it is imperative that each variable that influences the results be thoroughly analyzed.

2.2.5.2 Roll Control Effectiveness. The aileron correlation presented in Table 2-25 for a variety of configuration and Mach numbers shows good agreement for the rolling moment. The yawing moment results show larger relative differences. The extraction of the test data for the yawing moment is much more sensitive due to the magnitude of the values and thus may result in more significant inaccuracies.

Substantiation data for differentially deflected horizontal tail surfaces are presented in Table 2-27. The estimated rolling moment data for the configuration of Reference 3.11 with the low tail agrees with that presented in the DATCOM. The test values extracted from the stated reference are different than those quoted in Section 6.2.1.2 of the DATCOM. No methods exist for evaluating the side force and yawing moment characteristics of differentially deflected tails. The FQP sets the side force equal to zero (0) and uses data in the form of the parameter $C_{n_\delta}/C_{\ell_\delta}$, which was developed based on F-111A data, to compute the yawing moment. The data in Table 2-27 indicates that a more complete data base is necessary to develop the parameter $C_{n_\delta}/C_{\ell_\delta}$.

2.2.5.3 Directional Control Effectiveness. The rudder effectiveness presented in Table 2-28 indicates for the configurations tested that the methodology for the side force and yawing moment results in characteristics that compare well with test data. Although the rolling moment characteristics are not as good, they appear to compare reasonably with the test results.

TABLE 2-23

Stabilizer Effectiveness Substantiation Data

Ref.	Config.	M	$C_{z_{i_t}}$ (deg^{-1}) Calc	$C_{z_{i_t}}$ (deg^{-1}) Test	Percent Error	$C_{m_{i_t}}$ (deg^{-1}) Calc	$C_{m_{i_t}}$ (deg^{-1}) Test	Percent Error	Comment
5.1	F-104	0.25	-.0146	-.0141	3.5	-.0257	-.0250	2.8	
		0.80	-.0188	-.0190	-1.1	-.0333	-.0320	4.1	
		0.90	-.0204	-.0200	2.0	-.0364	-.0380	-4.2	
		0.95	-.0211	-.0203	3.9	-.0379	-.0370	2.4	
3.44		1.00	-.0219	-	-	-.0397	-.0335	18.5	
		1.06	-.0210	-	-	-.0386	-.0325	18.8	
		1.82	-.0123	-	-	-.0231	-.0200	15.5	
3.41	X-3	0.20	-.0108	-.0140	-22.9	-.0297	-.0300	-1.0	
3.43		0.40	-.0111	-.0100	11.0	-.0305	-.0280	8.9	
		0.60	-.0117	-.0110	6.4	-.0319	-.0305	4.6	
		0.70	-.0127	-.0125	1.6	-.0345	-.0330	4.5	
		0.80	-.0137	-.0138	-0.7	-.0375	-.0350	7.1	
		0.90	-.0146	-.0150	-2.7	-.0404	-.0388	4.1	
3.45	F-101	0.60	-.021	.005	-	-.0344	-.0295	16.6	
		0.80	-.0137	-.0008	-	-.0392	-.0322	21.7	
		0.85	-.0141	0	-	-.0406	-.0353	15.0	
		0.90	-.0145	-.0067	116.4	-.0420	-.0338	24.3	
8.1a	F-105	2.01	-.0058	-.0054	7.4	-.0122	-.0106	15.1	
1.2	25/70	0.2	-.0102	-.0140	-27.1	-.0126	-.0127	-0.8	No leading edge

TABLE 2-24

Elevator Effectiveness Substantiation Data

Ref.	Config.	M	$C_{z_{\delta_E}}$ (deg^{-1})		Percent	$C_{m_{\delta_E}}$ (deg^{-1})		Percent	Comment
			Calc	Test	Error	Calc	Test	Error	
3.35	F-102A	0.25	-.0146	-.0150	-2.7	-.0065	-.0063	3.2	Test Data Obtained from
		0.80	-.0165	-.0171	-3.5	-.0087	-.0085	2.4	Unpublished Wind Tunnel Data
		0.90	-.0177	-.0165	7.3	-.0100	-.0084	19.0	
		0.95	-.0179	-.0152	17.8	-.0106	-.0085	24.7	
3.47	XP-92	0.13	-.0239	-.0200	19.5	-.0119	-.0100	19.0	Horn Off
		0.13	-.0208	-.0190	9.5	-.0104	-.0090	15.6	Tip Off
2.1	Cruise	0.14	-.0085	-.0083	2.4	-.0220	-.0199	10.6	Windmilling
3.51	A4-D	0.6	-.0072	-.0069	4.3	-.0113	-.0104	8.7	
		0.7	-.0077	-.0072	6.9	-.0122	-.0108	12.9	
		0.8	-.0082	-.0071	15.5	-.0130	-.0105	23.8	
		0.9	-.0087	-.0056	55.4	-.0140	-.0084	66.7	
		1.0	-.0092	-.0042	119.0	-.0150	-.0065	130.8	
3.52	CV-880	0.20	-.0059	-.0051	15.7	-.0180	-.0152	18.4	Tail Lift Curve
		0.40	-.0062	-.0051	21.6	-.0189	-.0152	24.3	Slope Estimated by FQP
		0.60	-.0065	-.0053	22.6	-.0201	-.0160	25.6	
		0.80	-.0074	-.0056	32.1	-.0228	-.0166	37.3	
		0.90	-.0078	-.0053	47.2	-.0243	-.0157	54.8	
		0.95	-.0076	-.0051	49.0	-.0238	-.0145	64.1	
3.52	CV-800	0.20	-.0049	-.0051	-2.6	-.0151	-.0152	-0.3	Tail Lift Curve Slope from
		0.40	-.0050	-.0051	-0.8	-.0154	-.0152	1.4	Test Data
		0.60	-.0051	-.0053	-3.0	-.0159	-.0160	-0.7	
		0.80	-.0055	-.0056	-0.9	-.0171	-.0166	2.9	
		0.90	-.0057	-.0053	7.9	-.0178	-.0157	13.5	
		0.95	-.0055	-.0051	7.6	-.0172	-.0145	18.5	

TABLE 2-25

Aileron Effectiveness Substantiation Data

Ref.	Config	M	$C_{Y_{\delta_a}}$ (deg^{-1}) Calc	$C_{Y_{\delta_a}}$ (deg^{-1}) Test	ΔC_{Y_δ}	$C_{n_{\delta_a}}$ (deg^{-1}) Calc	$C_{n_{\delta_a}}$ (deg^{-1}) Test	ΔC_{n_δ}	$C_{\ell_{\delta_a}}$ (deg^{-1}) Calc	$C_{\ell_{\delta_a}}$ (deg^{-1}) Test	ΔC_{ℓ_δ}	Comment
3.18	High Wing	.25	0.0	.0001	-.0001	.00019	0.0	.00019	-.00198	-.00196	-.00002	Large Vertical
	FFR = 12	.80		0.0	0.0	.00026	.0001	.00016	-.00250	-.00246	-.00004	with Horizontal
		.90				.00028	.0001	.00018	-.00266	-.00276	.00010	α=6.3
		.95				.00028	.0001	.00018	-.00274	-.00294	.00020	
3.2	Plain Aileron	1.61	0.0	0.0	0.0	.00054	.00039	.00015	-.0010	-.0011	.00010	α=4.5
6.1	Basic Tail	1.61	0.0	0.0	0.0	.00001	.00028	-.00027	-.0010	-.0011	.00010	α=8.3
3.24	Plain	0.40	0.0	-	-	.00021	.00011	.00010	-.0021	-.0032	.0011	α=4.0
	Aileron	0.60				.00023	.00021	.00002	-.0022	-.0032	.0010	
		0.80				.00026	.00022	.00004	-.0025	-.0030	.0005	
		0.91				.00028	.00024	.00004	-.0027	-.0026	-.0001	
3.17	Plain Wing	0.15	0.0	-	-	.00021	.00029	-.00008	-.0022	-.0025	.0003	α=4.0
3.29	Clean	0.13	0.0	-.0004	.0004	.0012	.00060	.00060	-.00138	-.0014	.00002	α=8.2

TABLE 2-26

Spoiler Effectiveness Substantiation Data

$\alpha = 0°$

Ref.	Config	M	$C_Y)_{\delta_{sp}}$ Calc	$C_Y)_{\delta_{sp}}$ Test	ΔC_δ	$C_n)_{\delta_{sp}}$ Calc	$C_n)_{\delta_{sp}}$ Test	ΔC_{n_δ}	$C_\ell)_{\delta_{sp}}$ Calc	$C_\ell)_{\delta_{sp}}$ Test	ΔC_{ℓ_δ}	Comment
3.2	Spoiler 1	1.61	0.0	.010	-.01	-.0059	-.0055	-.0004	-.0091	-.0088	-.0003	$\delta_{sp}/c = 0.05$
	4			.015	-.015	-.0059	-.0065	.0006	-.0091	-.0085	-.0006	
	5			.008	-.008	-.0021	-.0023	.0002	-.0038	-.0047	.0009	
3.24	Plain Spoiler	0.40	0.0	-	-	-.0028	-.0027	-.0001	-.0144	-.0152	.0008	
		0.60				-.0028	-.0030	.0002	-.0150	-.0149	-.0001	
		0.80				-.0032	-.0025	.0007	-.0179	-.0165	-.0014	
		0.91				-.0037	-.0047	.0010	-.0190	-.0200	.0010	
		0.40				-.0050	-.0065	.0015	-.0285	-.0235	-.0050	$\delta_{sp}/c = 0.10$
		0.60				-.0050	-.0075	.0025	-.029[illegible]	-.0265	-.0031	
		0.80				-.0057	-.0072	.0015	-.0316	-.0279	-.0047	
		0.91				-.0062	-.0070	.0008	-.0360	-.0290	-.0070	
		0.40				-.0071	-.0075	.0004	-.0350	-.0325	-.0025	$\delta_{sp}/c = 0.15$
		0.60				-.0071	-.0075	.0004	-.0363	-.0349	-.0014	
		0.80				-.0080	-.0072	-.0008	-.0422	-.0304	-.0082	
		0.91				-.0085	-.0082	-.0003	-.0445	-.0350	-.0095	

TABLE 2-27

Differentially Deflected Horizontal Tail Substantiation Data

Ref.	Config	M	$C_{Y_{\delta_H}}$ (deg^{-1})		ΔC_{Y_δ}	$C_{n_{\delta_H}}$ (deg^{-1})		ΔC_{n_δ}	$C_{\ell_{\delta_H}}$ (deg^{-1})		ΔC_{ℓ_δ}	Comment
			Calc	Test		Calc	Test		Calc	Test		
3.18	High Wing FFR = 12	.25	0.0	.0019	-.0019	-.0003	-.00167	.00164	-.00091	-.00089	-.00002	Large Vertical with Horizontal $\alpha = 0°$
		.80		.0023	-.0023	-.0002	-.00218	.00198	-.00117	-.00096	-.00021	
		.90		.0033	-.0033	-.0003	-.00295	.00265	-.00124	-.00089	-.00035	
		.95		.0045	-.0045	-.0003	-.00372	.00342	-.0013	-.00103	-.00027	
3.11	Low H-Tail Clean Config	.15	0.0	.0020	-.0020	-.00022	-.00065	.00043	-.00077	-.0009	.00013	$\alpha = 0$
				.0018	-.0018	-.00018	-.00058	.00040	-.00077	-.00082	.00005	$\alpha = 4$
				.0017	-.0017	-.00014	-.00052	.00038	-.00075	-.00078	.00003	$\alpha = 8$
				.0018	-.0018	+.00006	-.00050	.00056	-.00067	-.00078	.00011	$\alpha = 16$
				.0018	-.0018	+.00024	-.00048	.00072	-.00064	-.00100	.00036	$\alpha = 20$
	Middle H-Tail Clean Config			0.0	0.0	-.00046	-.00010	-.00036	-.00159	-.0008	-.00079	$\alpha = 0$
				-.00013	.00013	-.00037	.00005	.00042	-.00159	-.00075	-.00084	$\alpha = 4$
				-.00033	.00033	-.00030	.00008	-.00038	-.00166	-.00079	-.00087	$\alpha = 8$
				-.00020	.00020	-	.00007	-	-	-.00061	-	$\alpha = 16$
				-.00013	.00013	-	.00012	-	-	-.00050	-	$\alpha = 20$
	High H-Tail Clean Config.			-.00067	.00067	-.00047	.00035	.00082	-.00163	-.00092	-.00071	$\alpha = 0$
				-.00080	.00080	-.00038	.00065	.00103	-.00163	-.00095	-.00068	$\alpha = 4$
				-.00107	.00107	-.00077	.00077	.00107	-.00167	-.00099	-.00068	$\alpha = 8$
				-.00107	.00107	-	.00080	-	-	-.00105	-	$\alpha = 16$
				-.00113	.00113	-	.00071	-	-	-.00103	-	$\alpha = 20$

TABLE 2-28

Rudder Effectiveness Substantiation Data

Ref.	Config	M	$C_{Y_{\delta_R}}$ (deg^{-1}) Calc	$C_{Y_{\delta_R}}$ (deg^{-1}) Test	ΔC_{Y_δ}	$C_{n_{\delta_R}}$ (deg^{-1}) Calc	$C_{n_{\delta_R}}$ (deg^{-1}) Test	ΔC_{n_δ}	$C_{\ell_{\delta_R}}$ (deg^{-1}) Calc	$C_{\ell_{\delta_R}}$ (deg^{-1}) Test	ΔC_{ℓ_δ}	Comment
3.18	Mid Wing,	.25	.00211	.0015	.00061	-.00136	-.00145	.00009	.00010	.00019	-.00009	Small Vertical,
	FFR = 12.0	.80	.00249	.0018	.00069	-.00163	-.00165	.00002	.00012	.00020	-.00008	with Horizontal
		.90	.00263	.0020	.00063	-.00174	-.00165	-.0009	.00013	.0020	-.00007	$\alpha = 6.3$
		.95	.00269	.0024	.00029	-.00181	-.00165	-.00016	.00013	.00023	-.00010	
		.25	.00239	.0021	.00029	-.00151	-.00190	.00039	.00014	.00019	-.00005	Large Vertical
		.80	.00282	.0024	.00042	-.00179	-.00226	.00047	.00017	.00030	-.00013	with Horizontal
		.90	.00296	.0030	-.00004	-.00192	-.00220	.00028	.00017	.00035	-.00018	$\alpha = 6.3$
		.95	.00304	.0030	.00004	-.00201	-.00213	.00012	.00017	.00035	-.00018	
	High Wing,	.25	.00211	.0019	.00021	-.00136	-.00169	.00033	.00010	.00012	-.00002	Small Vertical
	FFR = 12.0	.80	.00249	.0023	.00019	-.00163	-.00170	.00007	.00012	.00020	-.00008	with Horizontal
		.90	.00263	.0021	.00053	-.00174	-.00165	-.00009	.00013	.00025	-.00012	$\alpha = 6.3$
		.95	.00269	.0022	.00049	-.00181	-.00165	-.00016	.00013	.00020	-.00007	
	High Wing	.25	.00239	.0031	-.00071	-.00114	-.00160	.00046	.00018	.00031	-.00013	Large Vertical
	FFR = 10.92	.80	.00282	.0030	-.00018	-.00135	-.00180	.00045	.00022	.00035	-.00013	with Horizontal
		.90	.00296	.0033	-.00034	-.00144	-.00182	.00038	.00022	.00040	-.00018	$\alpha = 6.3$
		.95	.00304	.0030	.00004	-.00151	-.00175	.00024	.00022	.00040	-.00018	
6.1	Basic Tail	1.61	.00111	.0005	.00061	-.00046	-.00023	-.00023	0.0	.00006	-.00006	$\alpha = 8.3$
3.29	WBHV	0.13	.0048	.0040	.0008	-.0031	-.0033	.0002	.00056	.0006	-.00004	$\alpha = 0.0$
	$\delta_F = 0°$		.0048	.0041	.0007	-.0031	-.0035	.0004	.00012	.0001	.00002	

2.2.6 HIGH LIFT SYSTEM CHARACTERISTICS. The correlations presented are for the Medium STOL Transport (MST) model of Reference 1.3. The model had a wing with an aspect ratio of 8, quarter chord sweep of 25 degrees, and a taper ratio 0.33. All the configurations used for correlations are with leading-edge Krueger flaps deflected 55 degrees and with a leading edge jet momentum coefficient equal to 0.10.

The correlation studies for the high lift system methodology were limited to the MST configuration defined in Reference 1.3 due to unforeseen difficulties in the interpretation of the usage of the section lift curve slope ratio $c_{\ell_\alpha}/c_{\ell_\alpha})_{theory}$ and the flap effectiveness factors which delayed the start of the correlation studies. The values that are used depend on flap configuration, capture area ratio and amount of blowing and are used in various combinations. Logic had to be integrated into the high lift (HILIFT) and section (SCTSHN) routines to distinguish between the various conditions.

The Flying Qualities Program (FQP) computes increments due to the high lift system for lift curve slope, zero lift angle of attack, pitching moment at zero angle of attack, downwash gradient and angle of attack at zero downwash angle for systems that have no blowing. The increment in minimum drag coefficient, induced drag factor, and lift coefficient for minimum drag are also computed if it is a blown system. These increments are added to the clean aircraft characteristics to obtain total values as demonstrated for the lift of the triple slotted system.

Clean	Flap, $C_\mu = 1.0$
$C_{L_\alpha})_{WB} = 0.08178$	$\Delta C_{L_\alpha})_{SSF} = 0.0433$
$\alpha_{OL})_{WB} = -0.17$	$\Delta\alpha_{OL})_{SSF} = -35.9$

$$C_{L_\alpha})_{TO} = 0.08178 + 0.0433 = 0.1251$$

$$\alpha_{OL})_{TO} = -0.17 + -35.9 = -36.07$$

$$C_L)_{\alpha=0} = 0.1251\ [0 - (-36.07)] = 4.51$$

$$C_L)_{\alpha=10} = [10 - (-36.07)] = 5.76$$

The high lift correlations are presented in Figures 2-1 through 2-8. The data shows excellent agreement for the lift characteristics for all three flap configurations investigated. The pitching moment data indicates that further analysis and methodology development is required in this area. The present methodology was developed to give the increment in pitching moment at zero angle-of-attack and did not address the variation in slope with power.

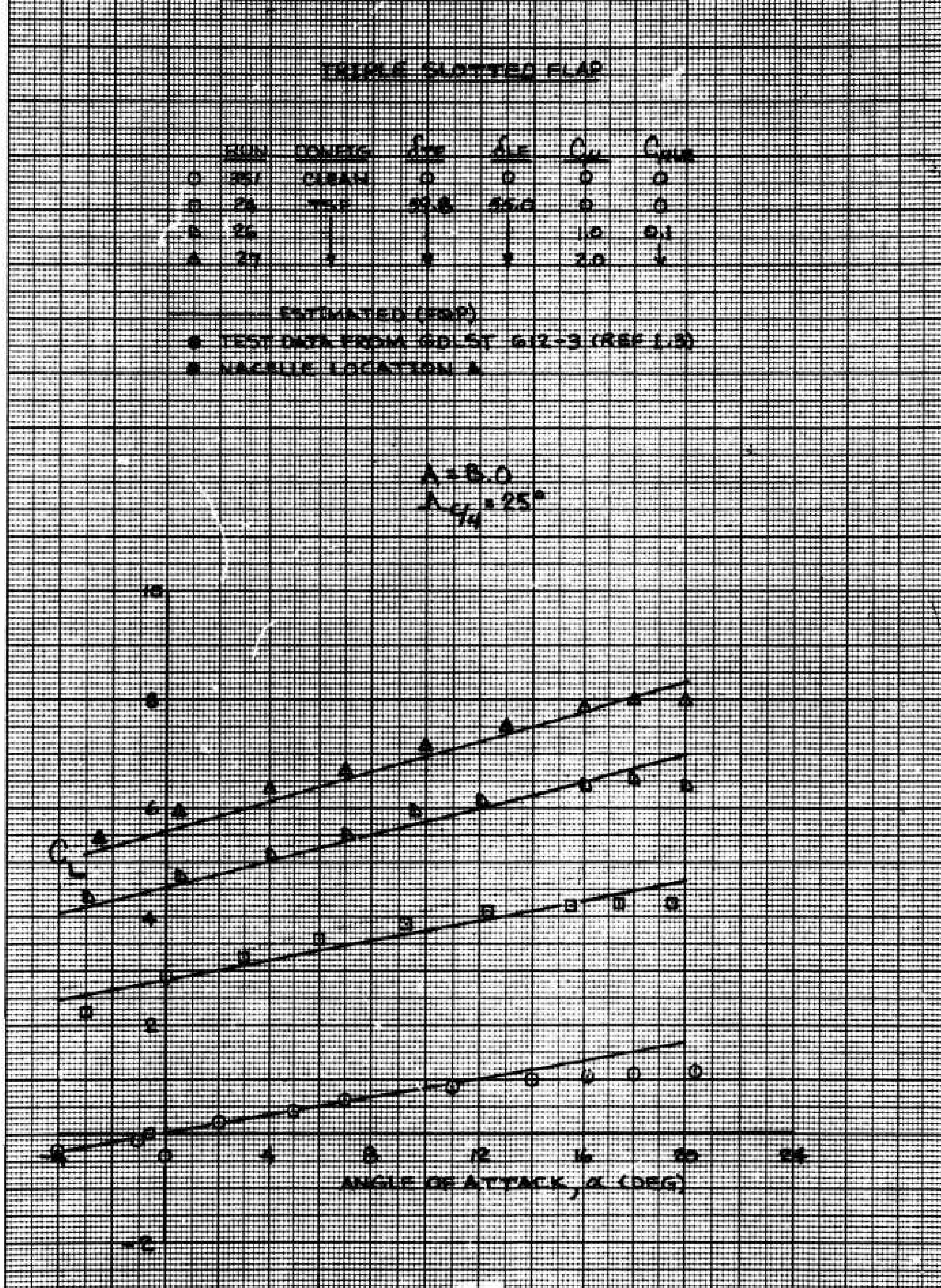
The data presented in Figures 2-2, 2-5, and 2-8 also utilized the estimated data for the clean aircraft C_{m_0} and $C_{m_{C_L}}$ which result in discrepancies that cannot be assessed to the high lift methodology validation. Table 2-29 shows a comparison of the increment in pitching moment at zero angle of attack, which provides a basis to evaluate the available high lift methodology. The results show reasonable accuracy except for the single slotted flap system with blowing. The tuft tests performed during the wind tunnel testing clearly indicated that the flow over the single slotted system was completely separated which accounts for the differences between the test and estimated data. This points out that a designer would not utilize a single slotted flap of this design for a blown system. If a single slotted flap was utilized the designer would probably have to perform optimization studies to develop the gap, overlap, chord ratio and deflection to ensure that the flow would stay attached.

The downwash correlation studies are presented in Figures 2-3 and 2-6 and show good agreement between the test and estimated characteristics.

Since the high lift correlations were limited in the present study, it was felt that including the correlation results from the methodology development study (Reference 1.3) was warranted. The lift characteristics correlations are presented in Figures 2-9 through 2-24. The pitching moment characteristics are presented in Tables 2-30 through 2-32. Table 2-33 summarized the configurations utilized in the downwash substantiation investigation. The correlation of the downwash characteristics is presented in Table 2-33 through 2-37.

Although the results indicate the accuracy levels to be good, it is imperative that the high lift methodology receive much more exposure before a just conclusion as to its validity can be drawn. The computerization of the methodology will allow for a larger data base to be developed on a wide variety of configurations, which will provide information for guidance in the decision as to its validity as a predesign concept.

FIGURE 2-1
HIGH LIFT CHARACTERISTICS



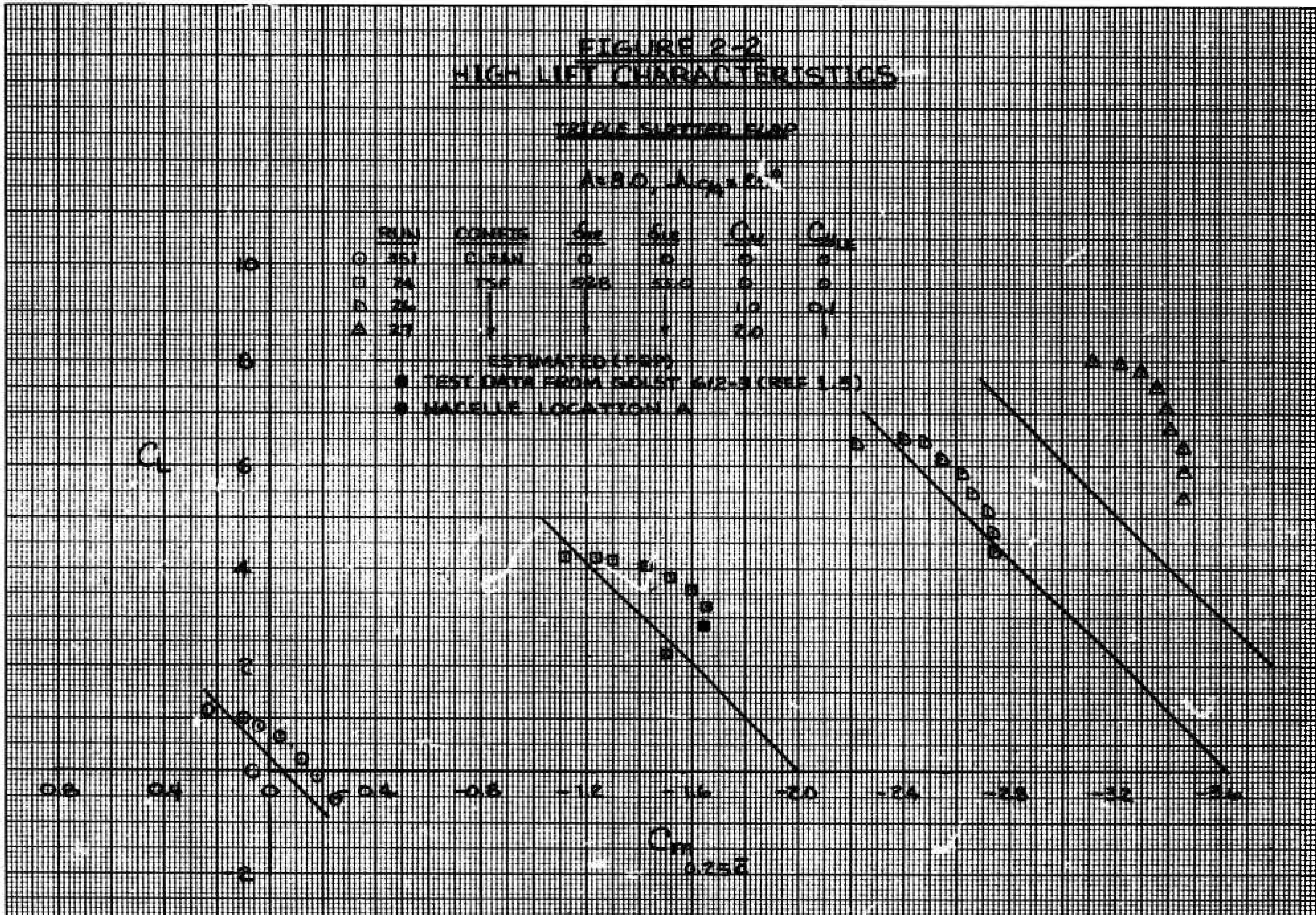


FIGURE 2-2
HIGH LIFT CHARACTERISTICS

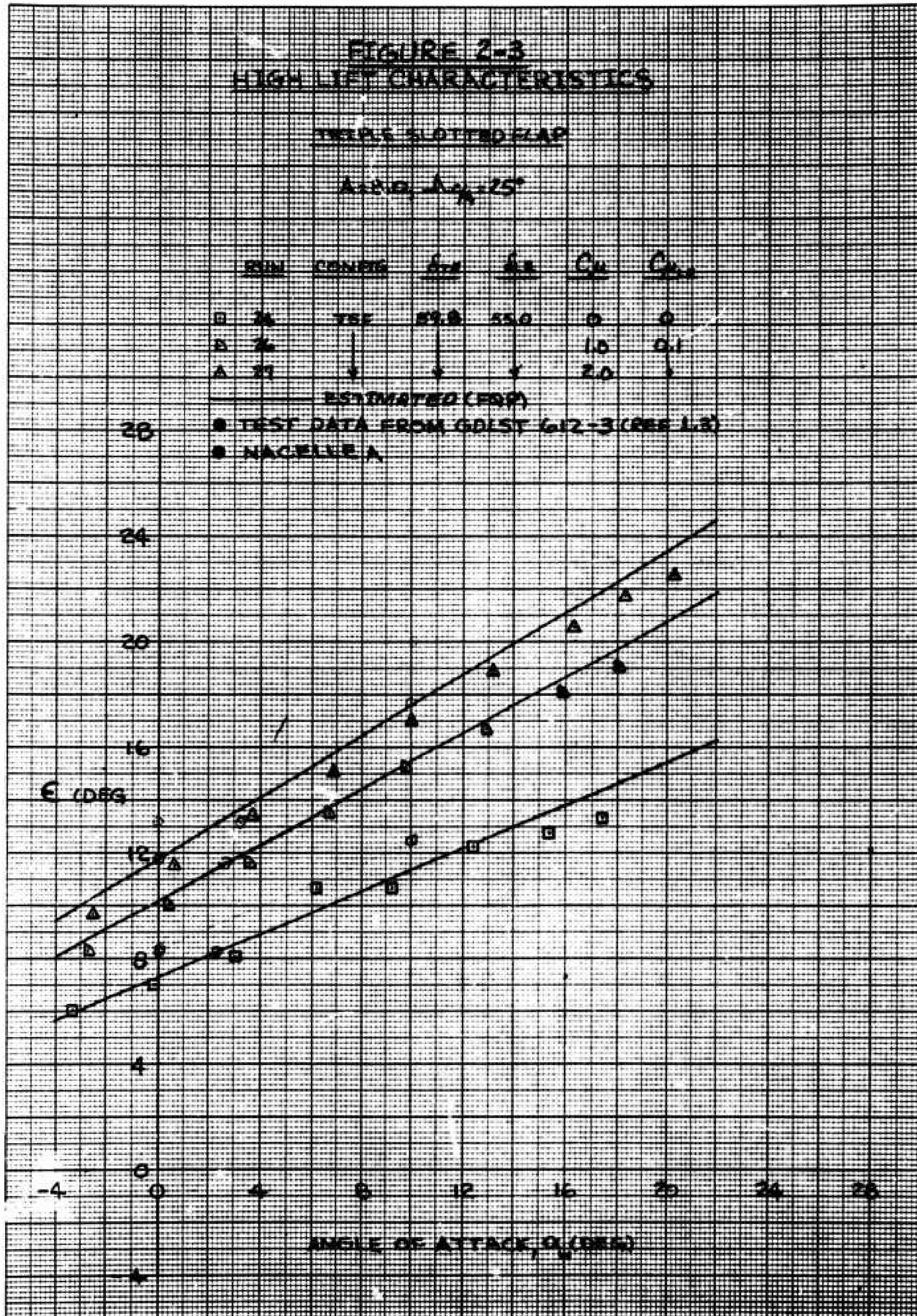


FIGURE 2-3
HIGH LIFT CHARACTERISTICS
TRIPLE SLOTTED FLAP
RUN
CONFIG
TSF
55.0
1.0
0.1
2.0
ESTIMATED (FQP)
TEST DATA FROM GDLST 612-3 (REF 1.3)
NACELLE A
28
24
20
16
12
8
4
0
-4
0
4
8
12
16
20
24
28
ε (DEG)
ANGLE OF ATTACK, α (DEG)

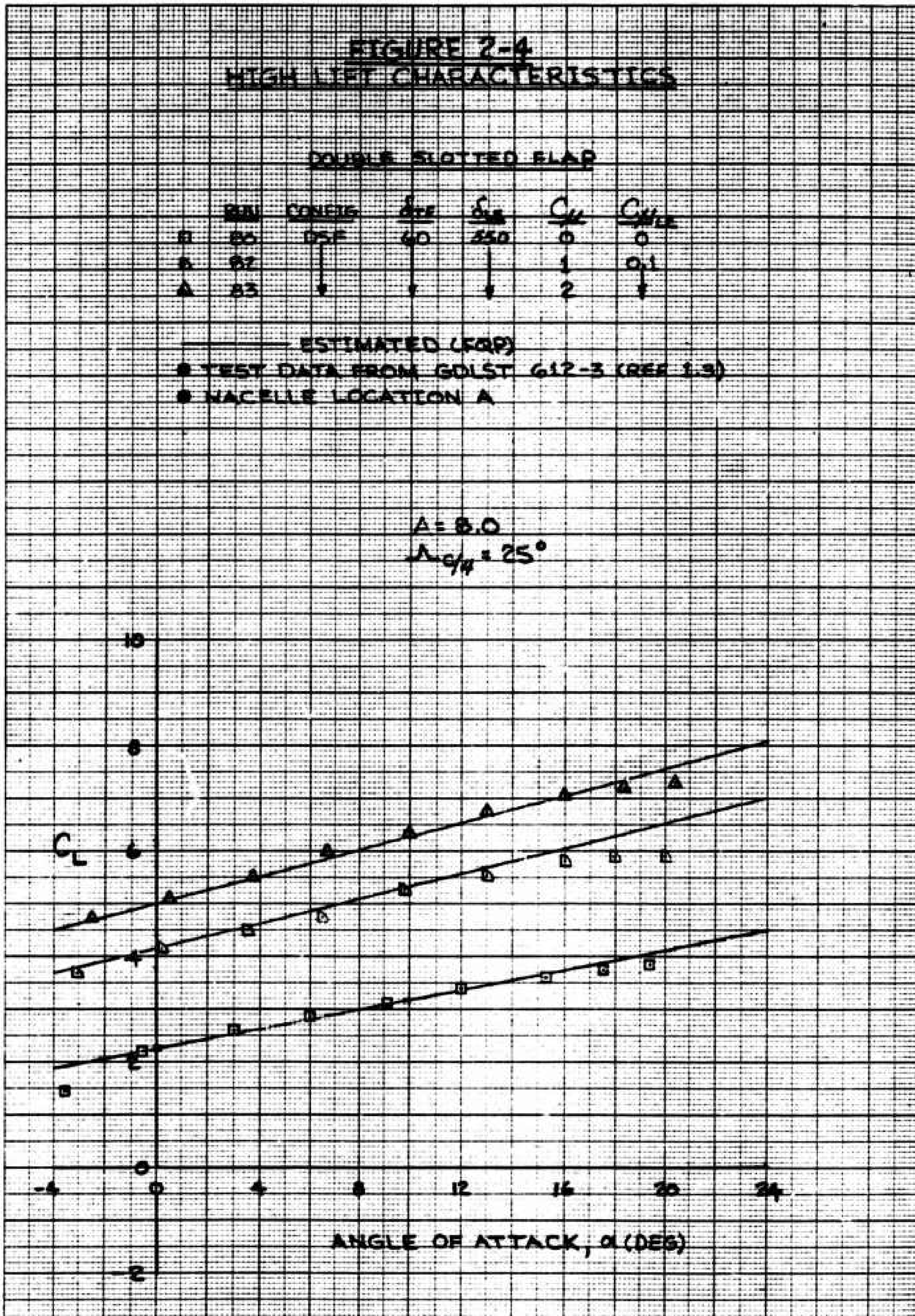
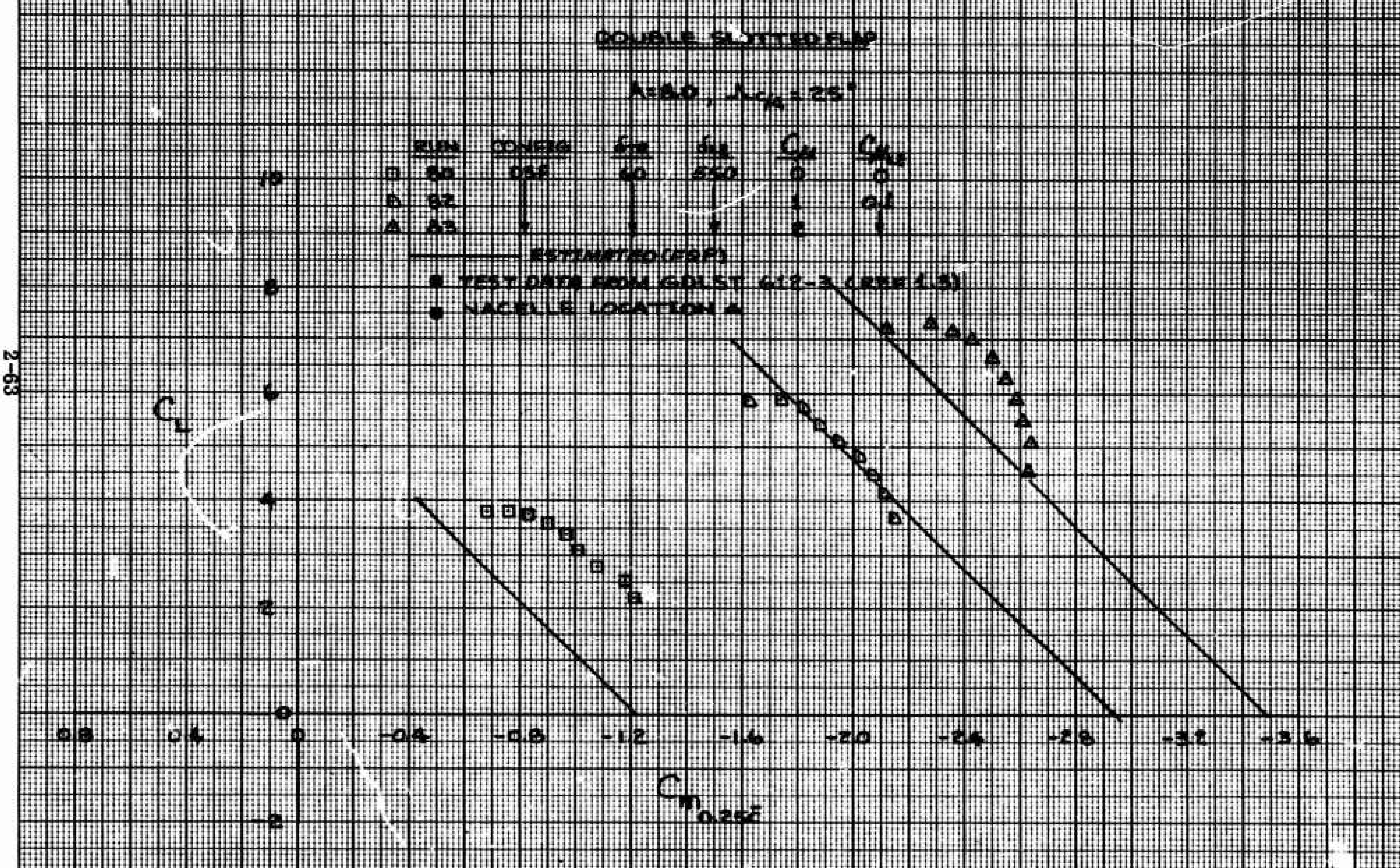


FIGURE 2-4
HIGH LIFT CHARACTERISTICS
DOUBLE SLOTTED FLAP
RUN CONFIG δ_{TE} δ_{LE} C_μ $C_{\mu_{LE}}$
86 DSF 60 550 0 0
87 1 0.1
83 2
ESTIMATED (FQP)
TEST DATA FROM GDLST 612-3 (REF 1.3)
NACELLE LOCATION A
A = 8.0
$\Lambda_{c/4} = 25°$
C_L
10
8
6
4
2
0
-2
-4
0
4
8
12
16
20
24
ANGLE OF ATTACK, α (DEG)

FIGURE 2-5

HIGH LIFT CHARACTERISTICS



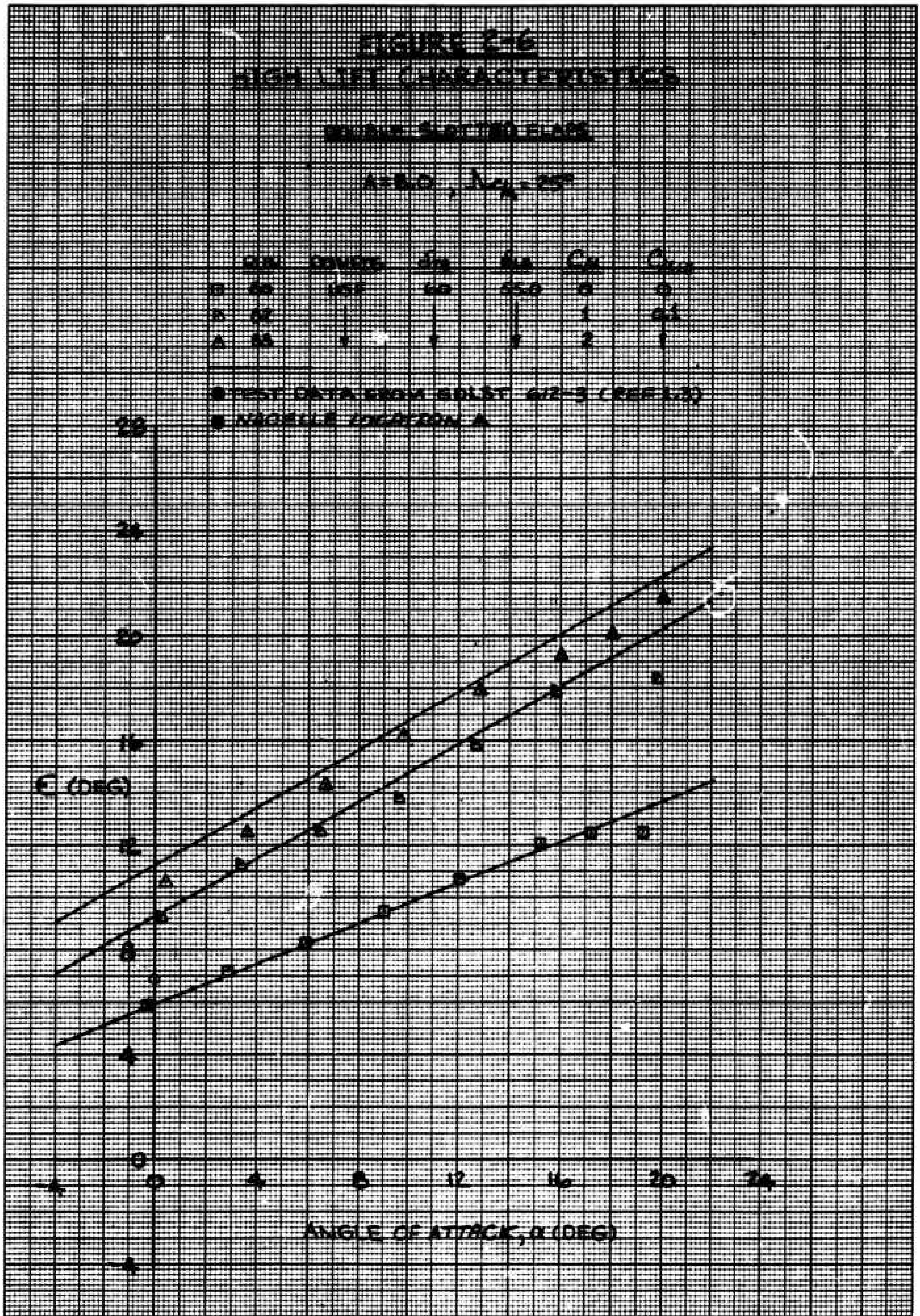
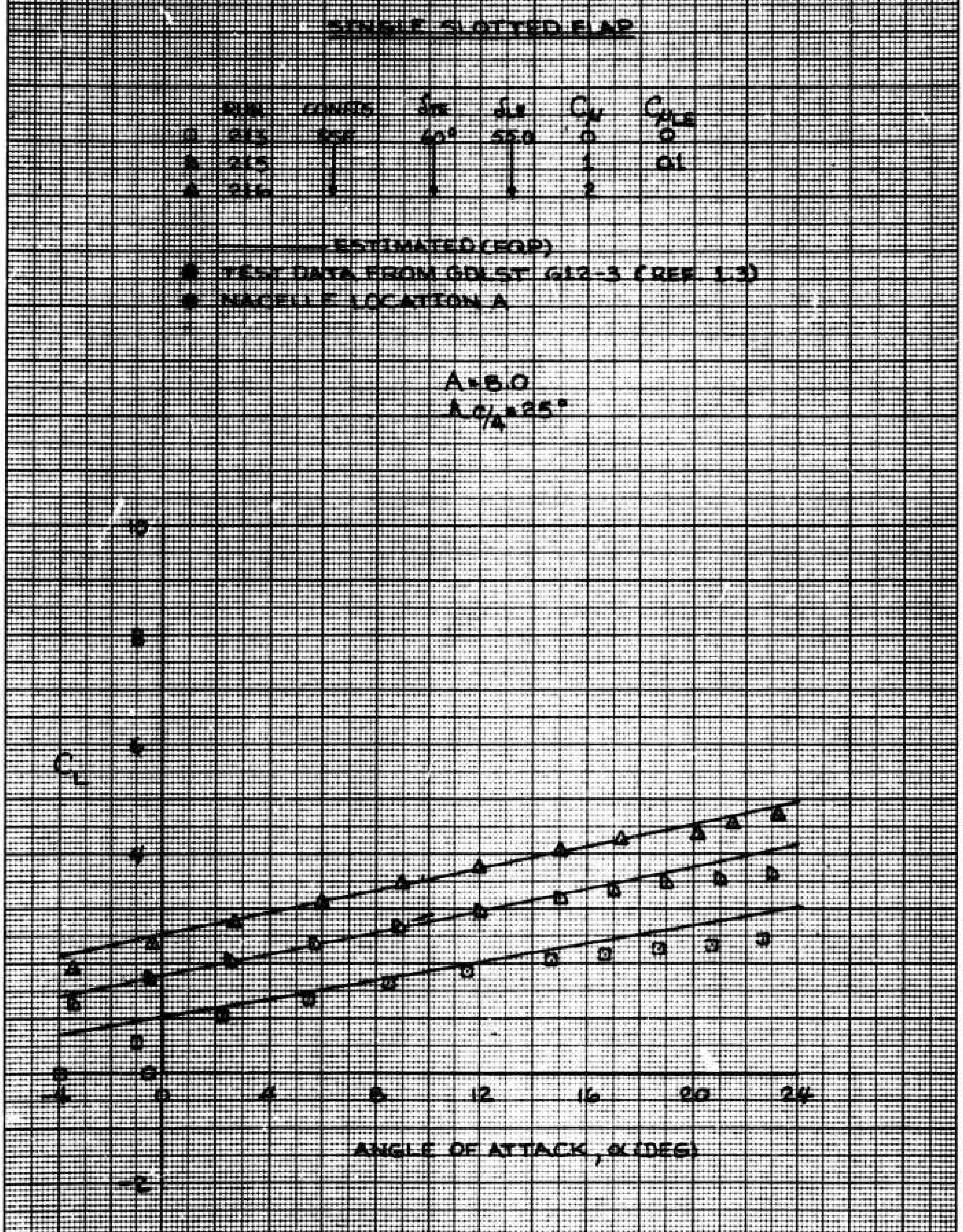

HIGH LIFT CHARACTERISTICS
28
24
20
16
ε (DEG)
12
8
4
0
-4
0
4
8
12
16
20
24
ANGLE OF ATTACK, α (DEG)
-4

FIGURE 2-7
HIGH LIFT CHARACTERISTICS



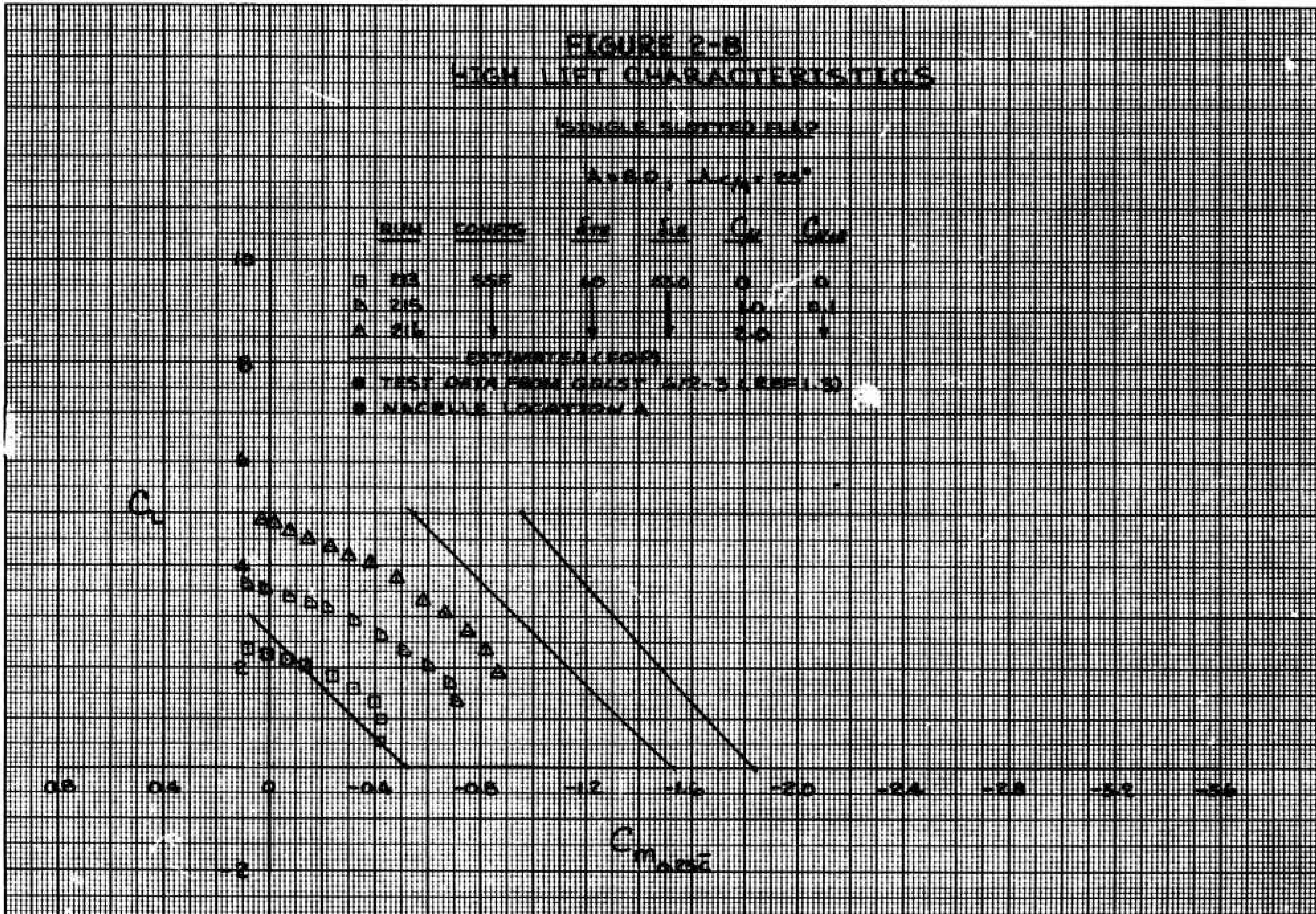


FIGURE 2-8
HIGH LIFT CHARACTERISTICS
SINGLE SLOTTED FLAP
ESTIMATED
TEST DATA FROM
NACELLE LOCATION A
C_L
$C_{m_{.25\bar{c}}}$
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2.0
-2.4
-2.8
-3.2
-3.6

TABLE 2-29

CORRELATION OF FLAP PITCHING MOMENT INCREMENT
AT ZERO ANGLE OF ATTACK

FLAP TYPE	δ_f	C_μ	$\Delta C_{m_{\alpha=0}}$	
			EST.	TEST
SSF	60	0	-.274	-.28
		1	-1.13	-.50
		2	-1.30	-.65
DSF	60	0	-.74	-1.06
		1	-2.09	-1.96
		2	-2.47	-2.50
TSF	60	0	-1.4	-1.5
		1	-2.7	-2.6
		2	-3.06	-3.33

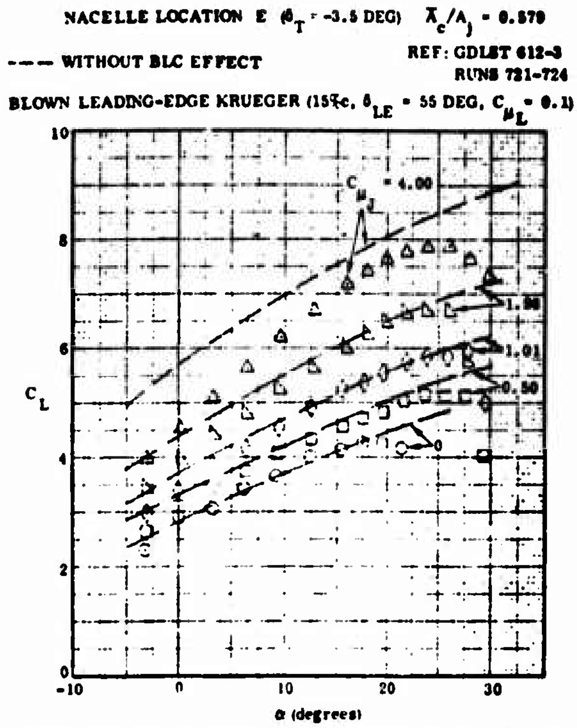


Figure 2-9. Correlation of Lift Generalized Methodology with EBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Triple-Slotted Flap (δ_f = 60 Degrees), Nacelles Low

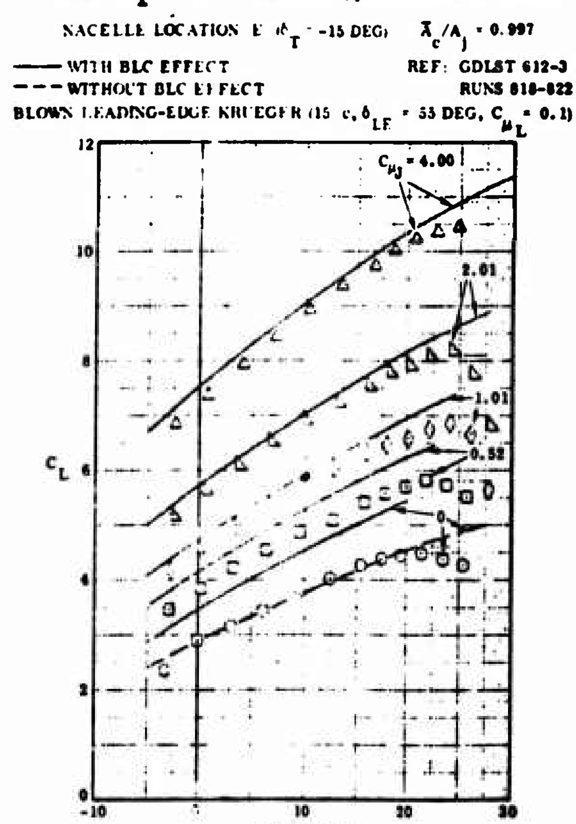


Figure 2-10. Correlation of Lift Generalized Methodology with EBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Triple-Slotted Flap (δ_f = 60 Degrees), Nacelles Low with Thrust Deflected Upward 15 Degrees

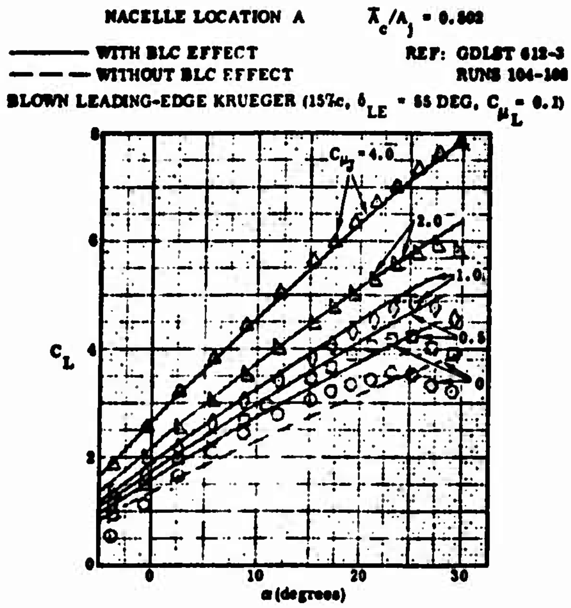


Figure 2-11. **Correlation of Lift Generalized Methodology with EBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Double-Slotted Flap (δ_f = 30 Degrees)**

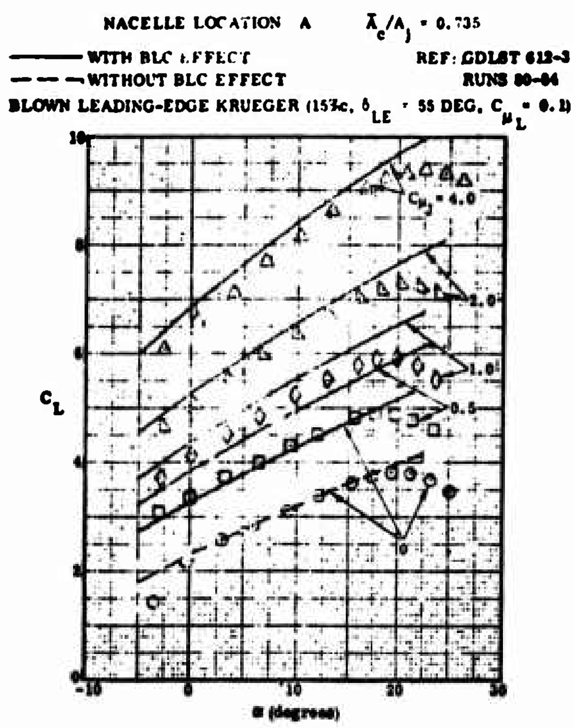


Figure 2-12. **Correlation of Lift Generalized Methodology with EBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Double-Slotted Flap (δ_f = 60 Degrees)**

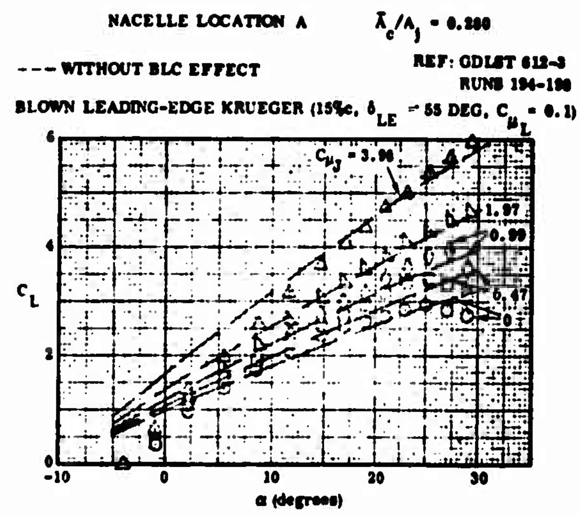


Figure 2-13. Correlation of Lift Generalized Methodology with EBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Single-Slotted Flap (δ_f = 30 Degrees)

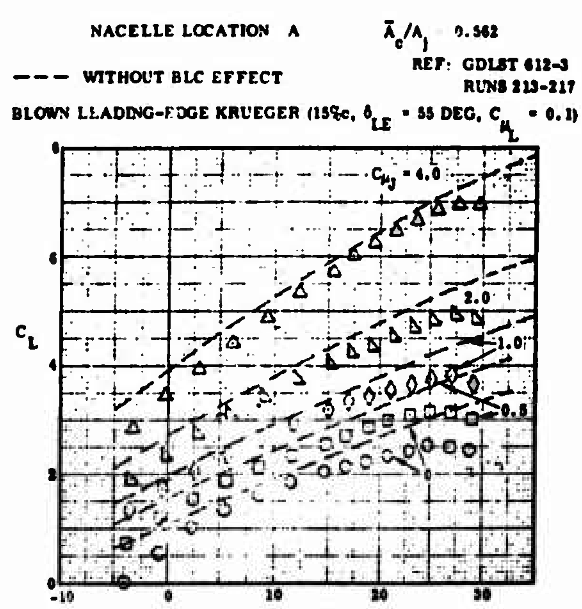


Figure 2-14. Correlation of Lift Generalized Methodology with EBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Single-Slotted Flap (δ_f = 60 Degrees)

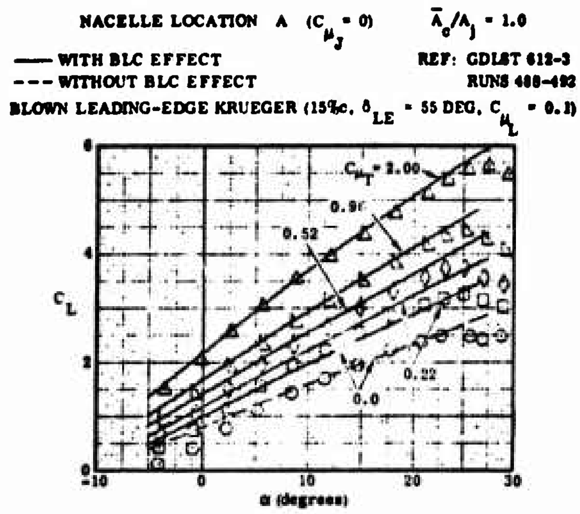


Figure 2-15. Correlation of Lift Generalized Methodology with IBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Plain Blown Flap (δ_f = 15 Degrees)

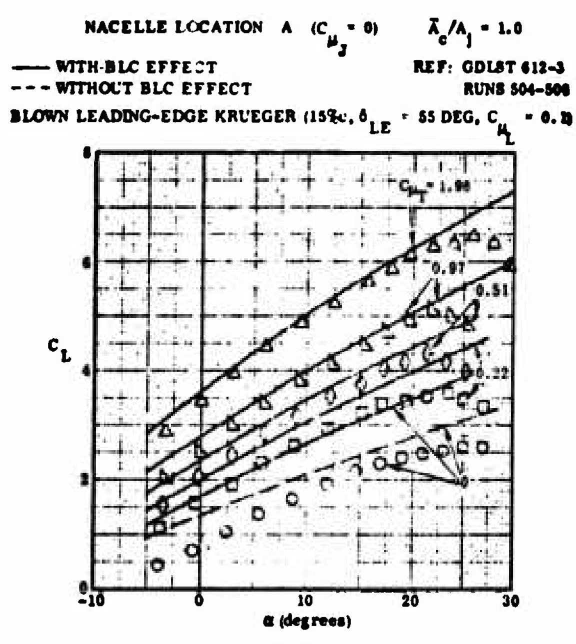


Figure 2-16. Correlation of Lift Generalized Methodology with IBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Plain Blown Flap (δ_f = 30 Degrees)

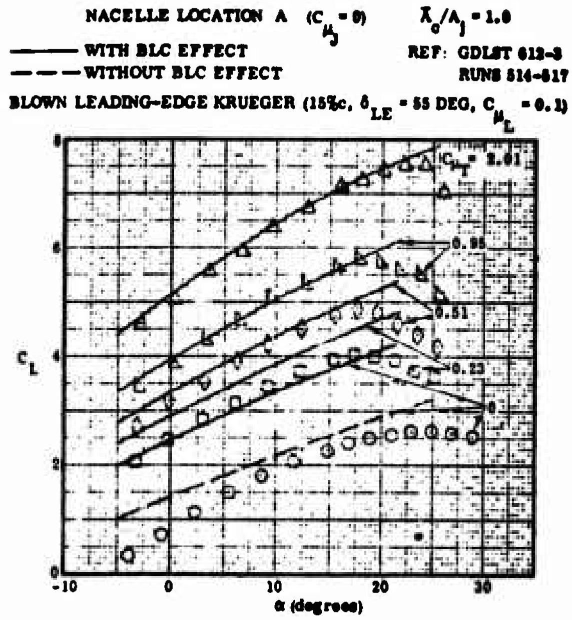


Figure 2-17. Correlation of Lift Generalized Methodology with IBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Plain Blown Flap (δ_f = 45 Degrees)

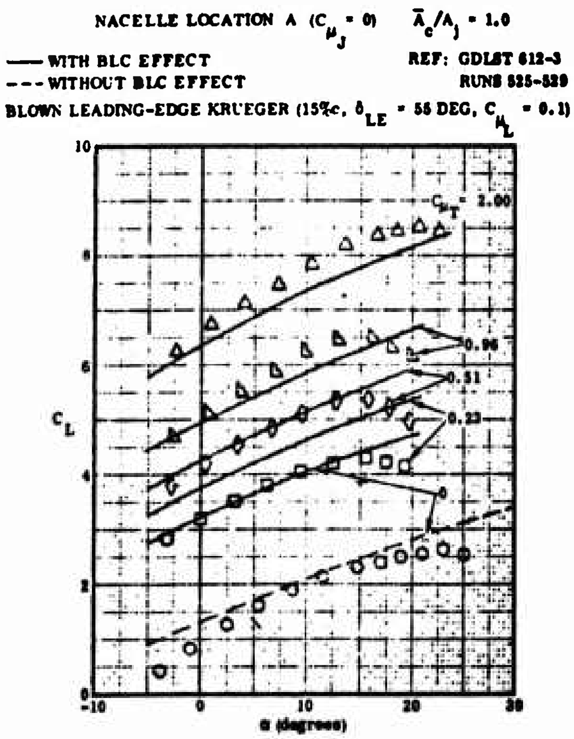


Figure 2-18. Correlation of Lift Generalized Methodology with IBF Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Plain Blown Flap (δ_f = 60 Degrees)

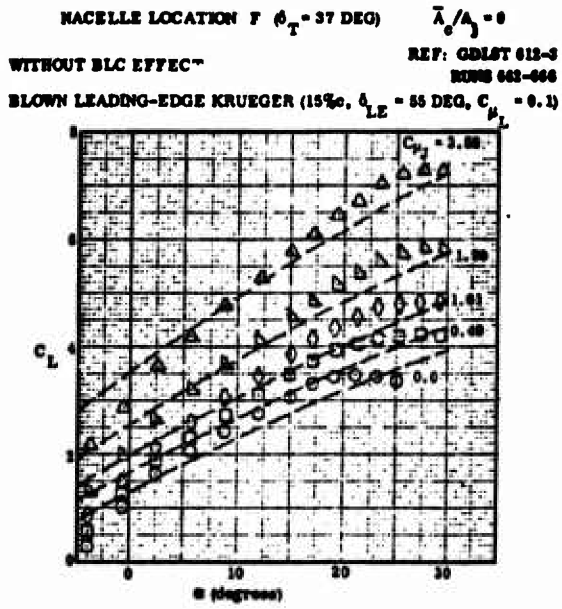


Figure 2-19. Correlation of Lift Generalized Methodology with MF/VT Test Data, A = 8, $\Lambda_{c/4}$ = 25 Degrees, Double-Slotted Flap (δ_f = 30 Degrees), Thrust Vectored Downward 37 Degrees

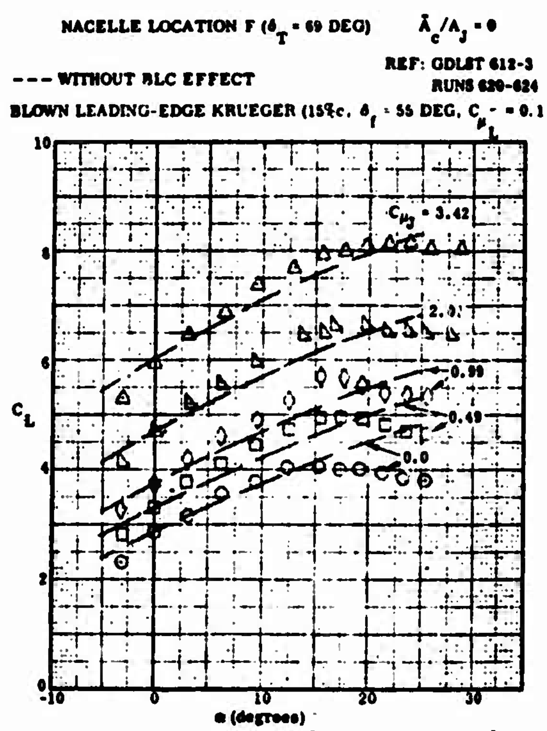


Figure 2-20. Correlation of Lift Generalized Methodology with MF/VT Test Data, A = 8, $\Lambda_{c/4}$ = 25 D grees, Triple-Slotted Flap (δ_f = 60 Degrees), Thrust Vectored Downward 69 Degrees

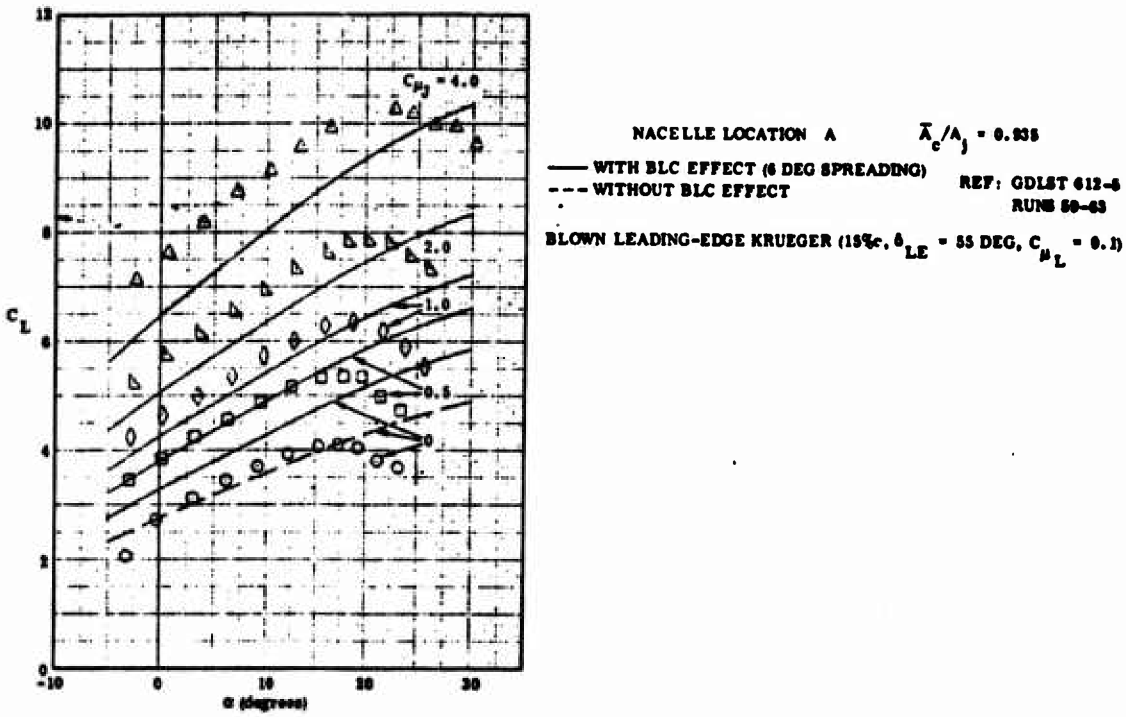


Figure 2-21. Correlation of Lift Generalized Methodology with EBF Test Data, A = 7.1, $\Lambda_{c/4}$ = 25 Degrees, Triple-Slotted Flap (δ_f = 60 Degrees)

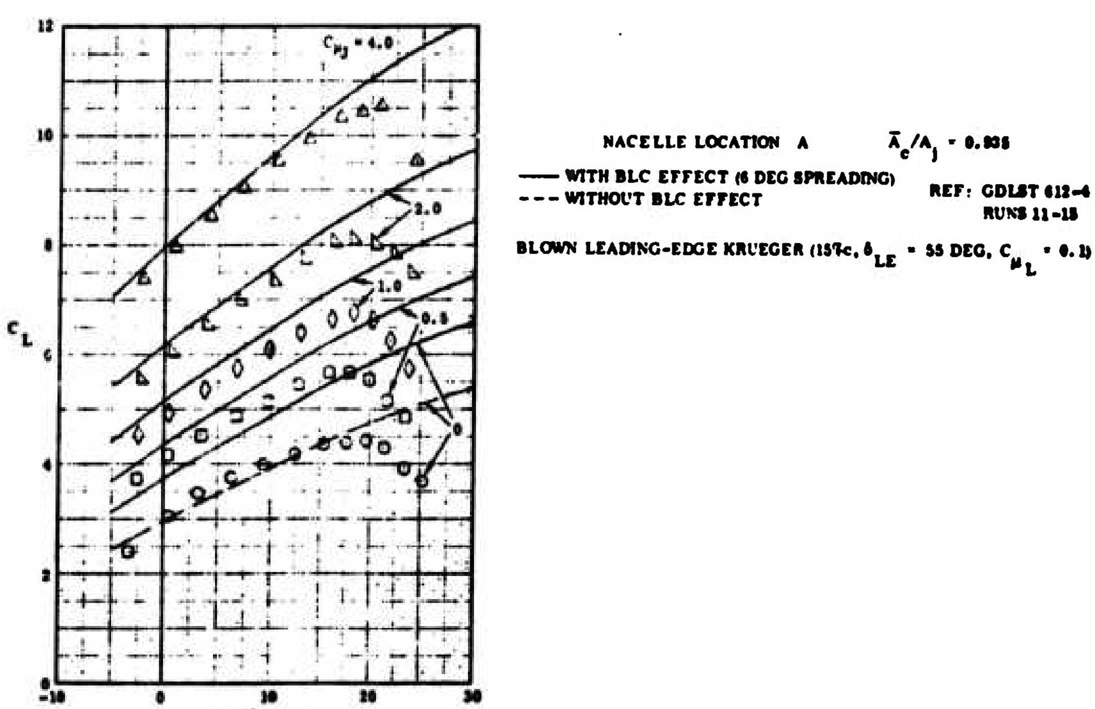


Figure 2-22. Correlation of Lift Generalized Methodology with EBF Test Data, A = 9.5, $\Lambda_{c/4}$ = 25 Degrees, Triple-Slotted Flap (δ_f = 60 Degrees)

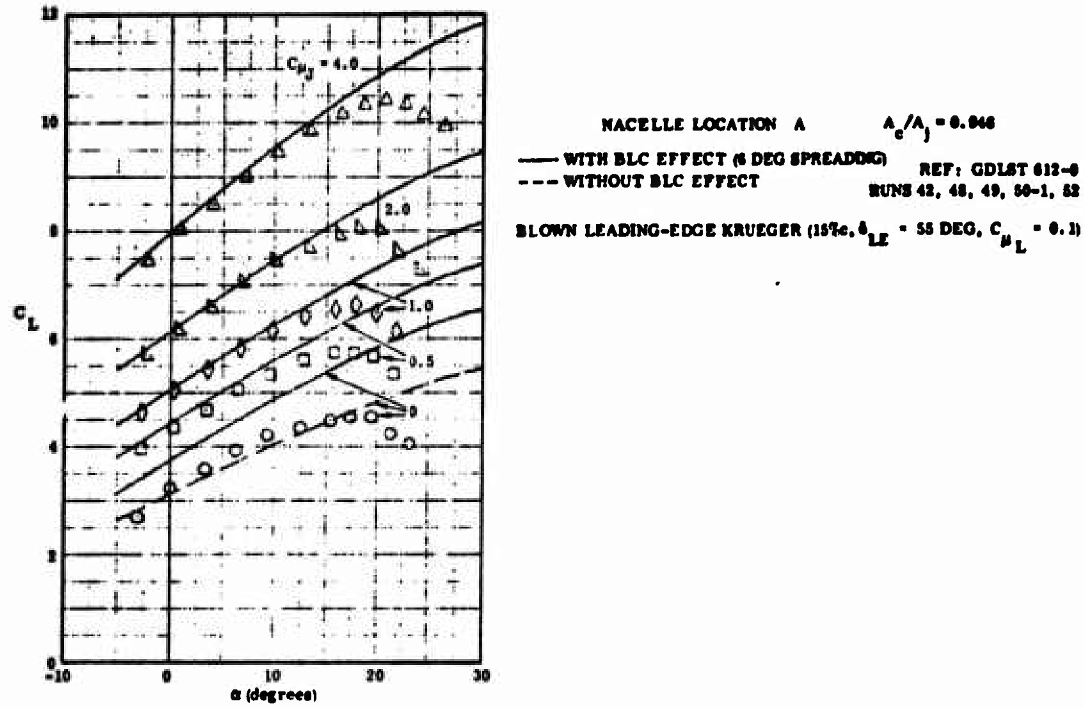


Figure 2-23. Correlation of Lift Generalized Methodology with EBF Test Data, A = 8.0, $\Lambda_{c/4}$ = 12.5 Degrees, Triple-Slotted Flap (δ_f = 60 Degrees)

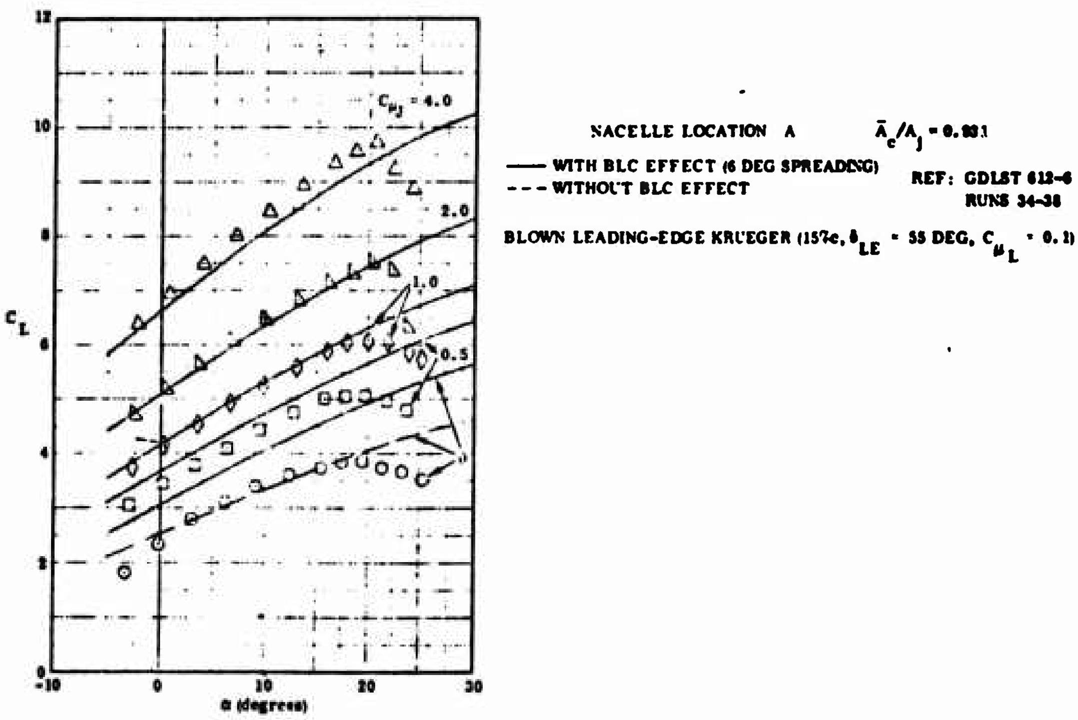


Figure 2-24. Correlation of Lift Generalized Methodology with EBF Test Data, A = 8.0, $\Lambda_{c/4}$ = 35 Degrees, Triple-Slotted Flap (δ_f = 60 Degrees)

Table 2-30. Mechanical Flap Data Correlation

δ_f (deg)	Flap Slots	A	$\Lambda_{c/4}$ (deg)	$\Delta C_m)_{\alpha=0}$ Test	$\Delta C_m)_{\alpha=0}$ Calculated	% Error
30	Double	8	12.5	-0.3965	-0.3965	14.2
60	Double	8	12.5	-0.9217	-0.6700	27.3
60	Triple	8	12.5	-1.3282	-1.2240	7.3
30	Single	8	25	-0.1806	-0.2614	44.7
60	Single	8	25	-0.1883	-0.3037	61.3
30	Double	8	25	-0.4888	-0.4836	1.0
60	Double	8	25	-0.9619	-0.7420	22.9
60	Triple	8	25	-1.4293	-1.3513	5.5
30	Double	9.5	25	-0.6215	-0.4685	24.6
60	Double	9.5	25	-0.9123	-0.7286	20.1
60	Triple	9.5	25	-1.4096	-1.3249	6.0
30	Double	7.14	25	-0.5804	-0.4922	15.2
60	Double	7.14	25	-0.8914	-0.7513	15.6
60	Triple	7.14	25	-1.3534	-1.3696	1.2
30	Double	8	35	-0.5809	-0.5638	2.9
60	Double	8	35	-0.9097	-0.8905	2.1
60	Triple	8	35	-1.3208	-1.5672	18.6

$$\text{Average Error} = \sum \frac{|\%\ \text{error}|}{n} = 17.1$$

Table 2-31. Internally Blown Flap Data Correlation

δ_f (deg)	Flap Slots	C_μ	$\Lambda_{c/4}$ (deg)	AR	k	$\Delta C_m)_{\alpha=0}$ Test	$\Delta C_m)_{\alpha=0}$ Calculated	% Error
30	Single	1	12.5	8.0	1.0	-1.1863	-1.11	6.4
30	Single	2	12.5	8.0	1.0	-1.434	-1.32	7.9
30	Plain	1	12.5	8.0	1.0	-0.9519	-0.967	1.7
30	Plain	2	12.5	8.0	1.0	-1.354	-1.37	1.2
60	Plain	1	12.5	8.0	1.0	-1.59	-1.67	5.0
60	Plain	2	12.5	8.0	1.0	-2.240	-2.33	4.0
30	Plain	1	25.0	8.0	1.0	-1.129	-1.12	0.8
30	Plain	2	25.0	8.0	1.0	-1.591	-1.58	0.6
30	Plain	1	25.0	8.0	0.81	-0.888	-0.906	2.0
30	Plain	2	25.0	8.0	0.81	-1.298	-1.28	1.4
45	Plain	1	25.0	8.0	1.0	-1.564	-1.47	6.0
45	Plain	2	25.0	8.0	1.0	-2.159	-2.17	0.5
60	Plain	1	25.0	8.0	1.0	-1.888	-1.81	4.1
60	Plain	2	25.0	8.0	1.0	-2.639	-2.48	6.0
60	Plain	1	25.0	8.0	0.81	-1.440	-1.47	2.1
60	Plain	2	25.0	8.0	0.81	-2.041	-2.01	1.5

$$\text{Average Error} = \sum \frac{|\%\ \text{error}|}{n} = 3.19$$

Table 2-32. Externally Blown Flap Data Summary Substantiation Correlation

	Flap Slots	Engine Position	$\Lambda_{c/4}$	AR	C_{μ_J}	$\Delta C_m)_{\alpha=0}$ Test	$\Delta C_m)_{\alpha=0}$ Calculated	% Error
60	Triple	E_3P_4*	12.5	8.0	1	-2.395	-2.473	3.3
		E_3P_4*	12.5	8.0	2	-3.093	-3.126	1.1
		E_3P_4*	12.5	8.0	4	-4.315	-4.192	2.9
60	Double	E_3P_4*	12.5	8.0	1	-1.7673	-1.667	5.7
		E_3P_4*	12.5	8.0	2	-2.288	-2.213	3.3
		E_3P_4*	12.5	8.0	4	-3.124	-3.091	1.1
30	Double	E_3P_4*	25	8.0	1	-1.0013	-1.059	5.8
		E_3P_4*	25	8.0	2	-1.247	-1.377	10.4
		E_3P_4*	25	8.0	4	-1.594	-1.383	13.2
		E_3P_4*	25	9.519	1	-0.9235	-1.004	8.7
		E_3P_4*	25	9.519	2	-1.0431	-1.2829	23.0
		E_3P_4*	25	9.519	4	-1.2018	-1.2360	2.8
60	Double	E_3P_4*	25	9.519	1	-1.8238	-1.6035	12.1
		E_3P_4*	25	9.519	2	-2.3306	-2.1147	9.3
		E_3P_4*	25	9.519	4	-3.1516	-2.9306	7.0
60	Triple	E_3P_4*	25	9.519	1	-2.538	-2.3522	7.3
		E_3P_4*	25	9.519	2	-3.2379	-2.9547	8.7
		E_3P_4*	25	9.519	4	-4.4362	-3.9206	11.4
30	Double	E_3P_4*	25	7.14	1	-0.8098	-1.1328	30.2
		E_3P_4*	25	7.14	2	-0.9777	-1.499	53.3
		E_3P_4*	25	7.14	4	-1.1383	-1.564	37.4
60	Double	E_3P_4*	25	7.14	1	-1.8966	-1.7120	9.7
		E_3P_4*	25	7.14	2	-2.4133	-2.3057	4.5
		E_3P_4*	25	7.14	4	-3.3385	-3.2692	2.1
60	Triple	E_3P_4*	25	7.14	1	-2.5033	-2.4719	1.3
		E_3P_4*	25	7.14	2	-3.2313	-3.169	1.9
		E_3P_4*	25	7.14	4	-4.5320	-4.3127	4.8
30	Double	E_3P_4*	35	8.0	1	-0.8654	-1.1347	31.1
		E_3P_4*	35	8.0	2	-0.9857	-1.5246	54.7
		E_3P_4*	35	8.0	4	-1.1463	-1.5585	36.0
60	Double	E_3P_4*	35	8.0	1	-1.8036	-1.6745	7.2
		E_3P_4*	35	8.0	2	-2.3096	-2.2572	2.3
		E_3P_4*	35	8.0	4	-3.1212	-3.1997	2.5
	Triple	E_3P_4*	35	8.0	1	-2.4219	-2.3851	1.5
		E_3P_4*	35	8.0	2	-3.0953	-3.0726	0.7
		E_3P_4*	35	8.0	4	-4.2465	-4.1613	2.0
	Triple	E_7P_8†	12.5	8.0	1	-1.6116	-1.7188	6.7
		E_7P_8†	12.5	8.0	2	-1.7474	-1.7852	2.2
		E_7P_8†	12.5	8.0	4	-1.8496	-1.7819	3.7
	Triple	E_7P_8†	25	8.0	1	-1.5947	-1.5307	4.0
		E_7P_8†	25	8.0	2	-1.7123	-1.4959	2.6
		E_7P_8†	25	8.0	4	-1.6350	-1.3085	20.0

Average error = $\frac{\sum|\%\ \text{error}|}{n}$ = 10.94

* E_3P_4 = Short Cowl, Short Pylon

† E_7P_8 = Long Cowl, Long Pylon

Table 2-33. Summary of Configurations Substantiated

Table No. (Sheet)	Wing Aspect Ratio	Wing Sweep Angles c/4 (deg)	Type of Trailing-Edge Flap	Type Augmentation	Trailing-Edge Flap Deflection (deg)	Normalized Displacement Of 0.25 $\bar{c}_H$: $\left(\frac{z_H}{\bar{c}_W}\right)$	Normalized Displacement Of 0.25 $\bar{c}_H$: $\left(\frac{x_H}{\bar{c}_W}\right)$	Downwash Calculation: Mean (% diff)	Downwash Calculation: Standard Deviation (% diff)
8-2(1)	9.52	25	Triple Slotted	Externally Blown	60	1.45	4.72	-0.61	2.86
8-2(2)	8.00	25	Triple Slotted	Externally Blown	60	1.45	4.72	-0.61	4.23
8-2(3)	7.14	25	Triple Slotted	Externally Blown	60	1.45	4.72	-0.16	3.05
8-2(4)	8.0	12.5	Triple Slotted	Externally Blown	60	1.45	4.72	0.16	2.21
8-2(5)	8.0	35	Triple Slotted	Externally Blown	60	1.45	4.72	0.29	3.35
8-3	8.0	25	Triple Slotted	Vectored Thrust	60	1.45	4.72	0.04	3.67
8-4	8.0	25	Plain	Internally Blown	60	1.45	4.72	0.55	5.06
8-5(1)	8.0	25	Double Slotted	Externally Blown	60	1.45	4.72	2.00	4.49
8-5(2)	8.0	25	Double Slotted	Externally Blown	60	0.55	4.72	0.52	5.93
8-5(3)	8.0	25	Double Slotted	Externally Blown	45	1.45	4.72	-1.37	3.90
8-5(4)	8.0	25	Double Slotted	Externally Blown	45	0.55	4.72	-0.54	7.15
8-5(5)	8.0	12.5	Double Slotted	Externally Blown	30	1.45	4.72	2.88	6.46
8-5(6)	8.0	12.5	Double Slotted	Externally Blown	30	0.55	4.72	-1.82	8.92
8-5(7)	8.0	12.5	Double Slotted	Externally Blown	30	1.45	2.92	2.07	7.04
8-5(8)	8.0	12.5	Double Slotted	Externally Blown	30	0.55	2.92	-5.85	6.25
						Downwash Calculation	Mean Value:	-0.09	—
							rms Value:	—	5.33

Table 2-34. Substantiation Data for Externally Blown Triple-Slotted Flap (Sheet 1)

$A = 9.52$ $\Lambda_{c/4} = 25$ deg $X_H = 4.72\ \bar{c}_W$ $Z_H = 1.45\ \bar{c}_W$

$\delta_{LE} = 55$ deg $\delta_f = 60$ deg $\delta_T = 0$ deg $\overline{A}_c/A_j = 0.935$

C_{μ_J}	$\alpha_W / \alpha_{W}(C_{L_{aero}})_{max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	-0.098	11.80	11.28	-4.41
	0.053	13.55	13.25	-2.21
	0.204	15.32	15.38	0.39
	0.355	17.64	17.55	-0.51
	0.480	19.77	20.11	1.72
	0.657	21.88	22.41	2.42
	0.805	23.92	24.78	3.60
	0.904	25.27	25.88	2.41
	1.000 (20.94 deg)	26.69	26.79	0.37
2.0	-0.116	10.22	9.65	-5.58
	0.040	11.75	11.45	-2.55
	0.193	13.59	13.38	-1.55
	0.347	15.36	15.34	-0.13
	0.500	17.41	17.24	-0.98
	0.652	19.08	19.39	1.62
	0.804	20.75	21.31	2.70
	0.902	21.99	22.09	0.64
	1.000 (20.46 deg)	23.27	22.36	-3.91
1.0	-0.142	8.63	8.58	-0.58
	0.031	10.35	10.08	-2.61
	0.206	12.07	11.76	-2.57
	0.375	13.44	13.38	-0.45
	0.548	15.22	15.19	-0.20
	0.719	16.66	16.74	0.48
	0.888	18.05	18.43	2.11
	1.000 (18.19 deg)	18.69	18.95	1.39
0	-0.181	5.53	5.08	-8.41
	0.003	7.26	6.89	-5.10
	0.182	8.77	8.40	-4.22
	0.359	9.93	9.71	-2.22
	0.536	10.91	10.91	0.00
	0.710	11.83	12.01	1.52
	0.884	12.79	13.05	2.03
	1.000 (19.55 deg)	12.88	13.40	4.04
			Mean % Difference =	-0.61
			Standard Deviation =	2.86

Table 2-34. Substantiation Data for Externally Blown Triple-Slotted Flap (Sheet 2)

$A = 8.0$ $\quad \Lambda_{c/4} = 25$ deg $\quad X_H = 4.72\ \bar{c}_W$ $\quad Z_H = 1.45\ \bar{c}_W$

$\delta_{LE} = 55$ deg $\quad \delta_f = 60$ deg $\quad \delta_T = 0$ deg $\quad \overline{A_c}/A_j = 0.935$

C_{μ_J}	$\alpha_W / \alpha_{W\left(C_{L_{aero}}\right)max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	-0.097	11.43	11.44	0.09
	0.045	13.11	13.24	0.99
	0.199	15.28	15.37	0.59
	0.351	17.33	17.61	1.62
	0.502	19.58	19.89	1.58
	0.654	21.44	22.30	4.01
	0.803	23.62	24.42	3.39
	0.902	24.71	25.91	4.86
	1.000 (20.76 deg)	26.20	27.14	3.59
2.0	-0.124	9.73	9.69	-0.41
	0.031	11.54	11.39	-1.30
	0.186	13.42	13.13	-2.61
	0.340	15.09	14.84	-1.66
	0.495	17.02	17.01	-0.06
	0.648	18.91	18.84	-0.37
	0.801	20.59	20.88	1.41
	0.903	21.75	21.96	0.97
	1.000 (20.31 deg)	22.49	22.65	0.71
1.0	-0.152	8.31	8.50	2.29
	0.023	10.03	10.01	-0.20
	0.198	11.63	11.58	-0.43
	0.371	13.52	13.08	-3.25
	0.544	15.24	14.95	-1.90
	0.715	16.69	16.37	-1.92
	0.887	18.12	17.95	-0.94
	1.000 (18.01 deg)	19.03	18.70	-1.73
0	-0.188	6.02	4.87	-19.10
	-0.004	7.00	6.81	-2.71
	0.179	8.05	8.23	2.24
	0.356	10.68	9.53	-10.77
	0.534	10.77	10.78	0.09
	0.709	12.25	11.89	-2.94
	0.885	12.79	12.83	0.31
	1.000 (17.43 deg)	13.35	13.35	0.0

Mean % Difference = -0.61
Standard Deviation = 4.23

Table 2-34. Substantiation Data for Externally Blown Triple-Slotted Flap (Sheet 3)

$A = 7.14$	$\Lambda_{c/4} = 25$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 1.45\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 60$ deg	$\delta_T = 0$ deg	$\bar{A}_c/A_j = 0.935$

C_{μ_J}	$\alpha_W / \alpha_W\left(C_{L_{aero}}\right)_{max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	-0.112	11.14	11.49	3.14
	0.040	13.14	13.33	1.45
	0.192	15.24	15.35	0.72
	0.342	17.03	17.64	3.58
	0.493	19.07	19.68	3.20
	0.644	21.37	21.95	2.71
	0.795	23.23	24.23	4.30
	0.904	24.40	25.62	5.00
	1.000 (20.75 deg)	25.89	26.65	2.94
2.0	-0.130	9.71	10.00	2.99
	0.027	11.52	11.76	2.08
	0.181	13.45	13.29	-1.19
	0.336	15.41	15.01	-2.60
	0.491	17.09	17.00	-0.53
	0.645	18.97	18.97	0.00
	0.799	20.84	20.85	0.05
	0.900	21.88	22.07	0.87
	1.000 (20.18 deg)	22.75	22.68	-0.31
1.0	-0.157	8.47	8.92	5.31
	0.018	10.42	10.34	-0.77
	0.194	11.94	11.83	-0.92
	0.369	13.70	13.46	-1.75
	0.542	15.38	15.09	-1.89
	0.715	16.86	16.59	-1.60
	0.886	18.52	18.12	-2.61
	1.000 (17.88 deg)	19.41	18.77	-3.30
0	-0.193	5.29	5.35	1.13
	-0.007	7.22	7.23	0.14
	0.174	8.91	8.54	-4.15
	0.352	10.52	9.83	-6.56
	0.531	11.44	11.06	-3.32
	0.708	12.94	12.25	-5.31
	0.884	14.12	13.15	-6.87
	1.000 (17.43 deg)	14.11	13.50	-4.32

Mean % Difference = -0.16
Standard Deviation = 3.06

Table 2-34. Substantiation Data for Externally Blown Triple-Slotted Flap (Sheet 4)

$A = 8.00$ $\quad \Lambda_{c/4} = 12.5$ deg $\quad X_H = 4.72\ \bar{c}_W$ $\quad Z_H = 1.45\ \bar{c}_W$

$\delta_{LE} = 55$ deg $\quad \delta_f = 60$ deg $\quad \delta_T = 0$ deg $\quad \overline{A_c}/A_j = 0.935$

C_{μ_J}	$\alpha_W/\alpha_W\left(C_{L_{aero}}\right)_{max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	-0.110	11.17	10.91	-2.31
	0.043	12.95	12.86	-0.69
	0.196	14.94	14.87	-0.47
	0.349	17.29	17.06	-1.33
	0.500	19.31	19.32	0.05
	0.653	21.64	21.66	0.09
	0.802	23.99	23.81	-0.75
	0.902	25.17	24.99	-0.72
	1.000 (20.59 deg)	26.68	25.99	-2.59
2.0	-0.125	9.64	9.58	-0.62
	0.031	11.42	11.31	-0.96
	0.186	13.17	12.99	-1.37
	0.341	15.12	15.02	-0.66
	0.496	17.08	17.06	-0.12
	0.647	18.89	19.08	1.01
	0.800	20.65	20.74	0.44
	0.901	21.88	21.56	-1.46
	1.000 (20.22 deg)	22.50	22.37	-0.93
1.0	-0.135	8.80	8.53	-3.07
	0.022	10.13	10.08	-0.49
	0.180	11.86	11.69	-1.43
	0.336	13.49	13.41	-0.59
	0.492	15.45	15.13	-2.07
	0.647	16.96	16.83	-0.77
	0.800	17.63	18.13	2.84
	0.902	18.92	18.82	-0.53
	1.000 (19.89 deg)	18.80	18.86	0.32
0	-0.162	5.27	5.36	1.71
	0.001	6.91	6.95	0.58
	0.160	8.39	8.34	-0.60
	0.321	9.82	9.80	-0.20
	0.479	10.88	11.17	2.67
	0.636	11.66	12.26	5.15
	0.793	12.86	13.36	3.89
	0.897	13.17	14.00	6.30
	1.000 (19.46 deg)	13.57	14.32	5.53
			Mean % Difference =	0.16
			Standard Deviation =	2.21

Table 2-34. Substantiation Data for Externally Blown Triple-Slotted Flap (Sheet 5)

$A = 8.00$	$\Lambda_{c/4} = 35$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 1.45\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 60$ deg	$\delta_T = 0$ deg	$\overline{A_c}/A_j = 0.935$

C_{μ_J}	$\alpha_W/\alpha_W\left(C_{L_{aero}}\right)_{max}$	$\epsilon_{measured}$	calculated	% Difference
4.0	-0.112	10.98	10.72	-2.37
	0.041	12.97	12.44	-4.09
	0.195	14.94	14.34	-4.02
	0.347	16.87	16.37	-2.96
	0.499	19.05	18.44	-3.20
	0.650	20.99	20.66	-1.33
	0.802	22.99	22.80	-0.83
	0.902	24.13	24.19	0.25
	1.000 (20.72 deg)	25.32	25.26	-0.24
2.0	-0.128	9.47	9.37	-1.06
	0.026	11.14	10.90	-2.15
	0.182	13.00	12.54	-3.54
	0.337	14.63	14.34	-1.98
	0.492	16.55	16.15	-2.42
	0.645	18.30	17.96	-1.86
	0.797	19.89	19.83	-0.30
	0.899	21.03	20.84	-0.90
	1.000 (20.33 deg)	22.04	21.86	-0.82
1.0	-0.140	7.94	8.42	6.05
	0.016	9.99	9.76	-2.30
	0.174	12.29	11.23	-8.62
	0.331	12.91	12.82	-0.70
	0.436	14.51	14.42	-0.62
	0.642	15.87	16.12	1.58
	0.798	17.34	17.73	2.25
	0.900	18.10	18.72	3.43
	1.000 (20.02)	18.71	19.29	3.10
0	-0.174	5.14	5.36	4.28
	-0.008	6.57	6.80	3.50
	0.155	8.11	8.26	1.85
	0.316	9.38	9.57	2.03
	0.476	10.55	10.78	2.18
	0.636	11.58	11.97	3.37
	0.792	12.54	12.86	2.55
	0.898	12.55	13.51	7.65
	1.000 (19.41 deg)	12.33	13.90	12.73
			Mean % Difference =	0.29
			Standard Deviation =	3.85

Table 2-35. Substantiation Data for Triple-Slotted Flap with Vectored Thrust

$A = 8.00$	$\Lambda_{c/4} = 25$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 1.45\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 60$ deg	$\delta_T = 90$ deg	$\overline{A_c}/A_j = 0.935$

C_{μ_J}	$\alpha_W/\alpha_W\left(C_{L_{aero}}\right)_{max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
3.4	-0.140	6.79	6.56	-3.39
	0.006	8.70	8.34	-4.14
	0.151	10.19	9.87	-3.14
	0.294	11.54	11.45	-0.78
	0.438	13.54	13.33	-1.55
	0.581	14.61	15.07	3.15
	0.722	16.54	16.64	0.60
	0.814	17.93	17.30	-3.51
	0.907	18.73	18.12	-3.26
	1.000 (21.83 deg)	19.68	18.83	-4.32
2.0	-0.186	6.67	6.69	0.30
	0.004	8.28	8.21	-0.85
	0.193	9.73	9.66	-0.72
	0.380	11.11	11.17	0.54
	0.568	12.81	12.81	0.00
	0.817	14.92	14.90	-0.13
	0.953	15.92	15.31	-3.83
	1.000 (16.70 deg)	17.01	15.90	-6.53
1.0	-0.179	6.14	6.60	7.49
	0.000	7.76	8.15	5.03
	0.179	9.14	9.61	5.14
	0.356	10.47	11.09	5.92
	0.534	11.93	12.50	4.78
	0.709	13.37	14.07	5.24
	0.886	14.78	15.69	6.16
	1.000 (17.65 deg)	15.64	16.15	3.26
0	-0.211	5.08	5.12	0.79
	-0.004	6.87	6.69	-2.62
	0.199	7.87	7.86	-0.13
	0.404	9.28	9.19	-0.97
	0.605	10.31	10.29	-0.19
	0.804	11.66	11.42	-2.06
	1.000 (15.36 deg)	12.50	11.89	-4.88
			Mean % Difference =	0.04
			Standard Deviation =	3.67

Table 2-36. Substantiation Data for Internally Blown Plain Flap

AR = 8.00	$\Lambda_{c/4}$ = 25 deg	X_H = 4.72 $\bar{c}_W$	Z_H = 1.45 $\bar{c}_W$
δ_{LE} = 55 deg	δ_f = 60 deg	δ_T = 0 deg	$\overline{A_c}/A_j$ = 0.935
			C_{μ_J} = 0

C_{μ_T}	$\alpha_W/\alpha_{W(C_{L_{aero}})max}$	ϵ measured	ϵ calculated	% Difference
2.0	-0.113	10.42	11.47	10.08
	0.029	11.89	13.11	10.26
	0.169	13.66	14.74	7.91
	0.309	15.69	16.46	4.91
	0.449	17.66	18.24	3.28
	0.589	19.36	20.26	2.01
	0.727	22.00	21.96	-0.18
	0.819	23.06	23.05	-0.04
	0.910	24.32	23.83	-2.01
	1.000 (22.27 deg)	25.16	24.49	-2.26
1.0	-0.176	9.00	9.55	6.11
	0.021	10.55	10.91	3.41
	0.218	12.31	12.30	-0.08
	0.415	14.24	13.70	-3.79
	0.610	16.04	15.05	-6.17
	0.806	17.58	16.48	-6.26
	1.000 (15.84 deg)	19.15	17.00	-11.23
0.5	-0.193	7.40	8.12	9.73
	0.008	8.81	9.45	7.26
	0.209	10.57	10.80	2.18
	0.407	11.66	11.99	2.83
	0.607	13.42	13.25	-1.27
	0.804	14.64	14.51	-0.89
	1.000 (15.59 deg)	16.09	15.26	-5.16
0.2	-0.210	6.09	6.72	10.34
	-0.006	7.38	7.89	6.91
	0.198	8.93	9.10	1.90
	0.399	9.97	10.18	2.11
	0.601	11.31	11.38	0.62
	0.801	12.54	12.31	-1.83
	1.000 (15.34 deg)	13.47	13.08	-2.90
0	-0.156	2.40	2.47	2.92
	-0.030	3.55	3.43	-3.38
	0.096	4.76	4.54	-4.62
	0.221	5.95	5.65	-5.04
	0.346	6.69	6.72	0.45
	0.470	8.22	7.82	-4.87
	0.593	9.18	8.60	-6.32
	0.675	9.84	9.53	-3.15
	0.757	10.40	10.15	-2.40
	0.838	10.56	10.76	1.89
	0.919	11.22	11.22	0.00
	1.000 (24.90 deg)	11.48	11.54	0.52
			Mean % Difference =	0.55
			Standard Deviation =	5.08

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 1)

$A = 8.00$	$\Lambda_{c/4} = 25$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 1.45\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 60$ deg	$\delta_T = 0$ deg	$A_e/A_j = 0.828$

C_{μ_J}	$\alpha_W/\alpha_W\left(C_{L_{aero}}\right)_{max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.029	12.23	12.35	0.98
	0.170	13.93	14.27	2.44
	0.310	16.04	16.33	1.81
	0.449	18.00	18.39	2.17
	0.589	20.39	20.66	1.32
	0.729	22.36	23.04	3.04
	0.820	23.37	24.21	3.59
	0.910	24.31	25.28	3.99
	1.000 (22.45 deg)	25.33	26.08	2.96
2.0	0.020	10.60	10.67	0.66
	0.177	12.47	12.25	-1.76
	0.332	14.26	13.93	-2.31
	0.489	16.19	15.85	-2.10
	0.644	17.95	17.70	-1.39
	0.798	19.26	19.41	0.78
	0.901	20.30	20.46	0.79
	1.000 (20.10 deg)	21.45	21.30	-0.70
1.0	0.011	9.30	9.19	-1.18
	0.170	11.28	10.63	-5.76
	0.327	12.58	12.17	-3.26
	0.485	13.83	13.78	-0.36
	0.640	15.91	15.40	-3.21
	0.796	17.91	16.97	-5.25
	0.898	17.63	17.75	0.68
	1.000 (19.83 deg)	18.41	18.28	-0.71
0	-0.016	5.94	5.14	-13.47
	0.149	7.21	6.44	-10.69
	0.309	8.33	7.44	-10.68
	0.469	9.50	8.66	-8.84
	0.629	10.79	9.99	-7.41
	0.790	12.07	11.22	-7.04
	0.895	12.47	11.91	-4.49
	1.000 (19.29 deg)	12.49	12.40	-0.72
			Mean % Difference =	2.00
			Standard Deviation =	4.49

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 2)

$A = 8.00$ $\Lambda_{c/4} = 25$ deg $X_H = 4.72\ \bar{c}_W$ $Z_H = 0.55\ \bar{c}_W$

$\delta_{LE} = 55$ deg $\delta_f = 60$ deg $\delta_T = 0$ deg $A_c/A_j = 0.935$

C_{μ_J}	$\alpha_W/\alpha_W\left(C_{L_{aero\,max}}\right)$		$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.029		16.11	16.04	-0.43
	0.170		18.39	18.53	0.76
	0.310		20.98	21.16	0.86
	0.449		23.02	23.70	2.95
	0.589		25.72	26.41	2.68
	0.729		27.80	29.18	4.96
	0.820		28.98	30.47	5.14
	0.910		29.82	31.59	5.94
	1.000	(22.45 deg)	30.42	32.38	6.44
2.0	0.020		14.04	13.93	-0.78
	0.177		16.35	16.01	-2.08
	0.332		18.28	18.12	-0.92
	0.489		20.57	20.54	-0.15
	0.644		22.93	22.76	-0.74
	0.798		24.43	24.75	1.31
	0.901		25.38	25.94	2.21
	1.000	(20.10 deg)	25.96	26.85	3.43
1.0	0.011		12.50	12.09	-3.29
	0.170		14.36	13.98	-2.65
	0.327		16.03	15.94	-0.56
	0.485		17.94	17.94	0.00
	0.640		19.77	19.89	0.61
	0.796		21.31	21.75	2.06
	0.898		21.57	22.66	5.05
	1.000	(19.83 deg)	21.99	23.13	5.18
	-0.016		7.35	6.88	-6.39
	0.149		9.50	8.59	-9.58
	0.309		11.02	9.87	-10.44
	0.469		12.70	11.42	-10.08
	0.629		13.72	13.06	-4.81
	0.790		15.22	14.52	-4.60
	0.895		14.89	15.33	2.96
	1.000		12.98	15.86	22.19
				Mean % Difference =	0.52
				Standard Deviation =	5.93

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 3)

$A = 8.00$	$\Lambda_{c/4} = 25$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 145\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 45$ deg	$\delta_T = 0$ deg	$A_c/A_j = 0.740$

C_{μ_J}	$\alpha_W / \alpha_{W\left(C_{L_{aero}}\right)_{max}}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.006	10.18	10.00	-1.77
	0.128	11.93	11.72	-1.76
	0.249	13.64	13.57	-0.51
	0.367	15.59	15.51	-0.51
	0.488	17.81	17.72	-0.51
	0.608	20.06	20.23	0.85
	0.687	21.46	21.61	0.70
	0.769	22.73	23.06	1.45
	0.846	24.37	24.91	2.22
	0.923	25.47	25.98	2.00
	1.000 (26.22 deg)	26.94	26.84	-0.37
2.0	0.001	8.84	8.50	-3.85
	0.133	10.32	10.00	-3.10
	0.265	12.13	11.58	-4.53
	0.395	13.64	13.41	-1.69
	0.526	15.57	15.20	-2.38
	0.657	17.48	17.46	-0.11
	0.742	18.19	18.51	1.76
	0.829	19.73	19.90	0.86
	0.915	20.76	20.92	0.77
	1.000 (23.92 deg)	21.67	21.84	0.78
1.0	-0.005	7.83	7.35	-6.13
	0.142	9.04	9.02	-0.22
	0.285	10.66	10.27	-3.66
	0.430	12.03	11.78	-2.08
	0.574	13.85	13.41	-3.18
	0.716	15.27	15.08	-1.24
	0.812	16.35	16.44	0.55
	0.907	17.03	17.15	0.70
	1.000 (21.68 deg)	17.79	18.06	1.52
0	-0.017	5.27	4.62	-12.33
	0.134	6.93	6.18	-10.82
	0.280	8.40	7.65	-8.93
	0.425	9.53	8.88	-6.82
	0.572	10.36	10.21	-1.45
	0.716	11.49	11.35	-1.22
	0.811	11.93	12.07	1.17
	0.906	12.64	12.67	0.24
	1.000 (21.28 deg)	11.86	13.07	10.20

Mean % Difference = -1.37
Standard Deviation = 3.90

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 4)

$A = 8.00$	$\Lambda_{c/4} = 25$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 0.55\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 45$ deg	$\delta_T = 0$ deg	$A_c/A_j = 0.740$

C_{μ_J}	$\alpha_W/\alpha_{W(C_{L_{aero}})max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.006	13.38	12.47	-6.80
	0.128	15.76	14.74	-6.47
	0.249	17.60	17.12	-3.11
	0.367	20.25	19.53	-3.51
	0.488	22.55	22.22	-1.46
	0.608	25.15	25.19	0.16
	0.687	26.67	26.76	0.34
	0.765	27.91	28.37	1.67
	0.846	29.62	30.45	2.80
	0.923	30.64	31.55	2.97
	1.000 (26.62 deg)	31.54	32.41	2.76
2.0	0.001	11.58	10.81	-6.65
	0.133	13.20	12.77	-3.26
	0.265	15.49	14.81	-4.39
	0.395	17.43	17.09	-1.95
	0.526	19.84	19.27	-2.97
	0.657	22.24	21.97	-1.21
	0.742	22.93	23.14	0.92
	0.829	23.95	24.72	3.22
	0.915	24.52	25.82	5.30
	1.000 (23.92 deg)	24.99	26.79	7.20
1.0	-0.005	10.26	9.57	-6.73
	0.142	11.74	11.32	-3.58
	0.285	13.86	13.26	-4.33
	0.430	15.52	15.15	-2.38
	0.574	17.27	17.14	-0.75
	0.716	18.97	19.12	0.79
	0.812	19.86	20.73	4.38
	0.907	19.79	21.50	8.64
	1.000 (21.68 deg)	20.09	22.50	12.00
0	-0.017	6.87	6.17	-10.19
	0.134	9.13	8.24	-9.75
	0.280	10.45	10.14	-2.97
	0.425	12.04	11.69	-2.91
	0.572	12.79	13.32	4.14
	0.716	13.60	14.65	7.72
	0.811	13.79	15.47	12.18
	0.906	12.51	16.10	28.70
	1.000 (21.28 deg)	11.32	16.52	----

Mean % Difference = 0.54
Standard Deviation = 7.15

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 5)

$A = 8.00$	$\Lambda_{c/4} = 12.5$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 1.45\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 30$ deg	$\delta_T = 0$ deg	$A_c/A_j = 0.502$

C_{μ_J}	$\alpha_W/\alpha_W\left(C_{L_{aero}}\right)_{max}$		$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.099		7.79	9.11	16.94
	0.212		9.49	10.68	12.54
	0.326		11.30	12.43	10.00
	0.439		13.41	14.28	6.49
	0.551		15.62	16.34	4.61
	0.628		17.30	17.97	3.87
	0.702		18.88	19.40	2.75
	0.776		20.39	20.83	2.16
	0.851		21.71	22.35	2.95
	0.925		23.36	23.47	0.47
	1.000	(27.77 deg)	25.01	24.91	-0.41
2.0	0.099		6.64	7.33	10.39
	0.212		8.54	8.81	3.16
	0.326		10.07	10.50	4.27
	0.439		11.41	12.20	6.92
	0.553		13.55	14.22	4.94
	0.628		15.00	15.45	3.00
	0.703		16.21	16.86	4.01
	0.778		17.61	18.24	3.58
	0.851		18.84	19.70	4.56
	0.926		20.05	20.63	2.89
	1.000	(27.61 deg)	20.97	21.39	2.00
1.0	0.106		6.64	6.38	-3.92
	0.228		8.01	7.73	-3.50
	0.352		9.42	9.44	0.21
	0.474		10.87	11.01	1.29
	0.596		12.28	12.80	4.23
	0.678		13.69	14.08	2.85
	0.758		14.61	15.14	3.63
	0.839		15.65	16.40	4.86
	0.921		16.73	17.99	7.53
	1.000	(25.47 deg)	17.31	18.17	4.97
0	0.103		5.45	4.29	-21.28
	0.228		6.71	5.79	-13.71
	0.353		7.89	7.29	-7.60
	0.475		9.29	8.82	-5.06
	0.597		10.61	10.29	-3.02
	0.678		11.05	11.15	0.90
	0.760		11.74	12.08	2.90
	0.839		12.09	12.89	6.62
	0.920		12.82	13.69	6.79
	1.000	(25.25 deg)	13.30	14.30	7.52
				Mean % Difference =	2.58
				Standard Deviation =	6.45

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 6)

$A = 8.00$	$\Lambda_{c/4} = 12.5$ deg	$X_H = 4.72\ \bar{c}_W$	$Z_H = 0.55\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 30$ deg	$\delta_T = 0$ deg	$\bar{A}_o/A_j = 0.502$

C_{μ_J}	$\alpha_W/\alpha_W(C_{L_{aero}})_{max}$		$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.099		11.57	10.46	-9.59
	0.212		13.81	12.77	-7.53
	0.326		16.18	14.96	-7.54
	0.439		18.46	17.28	-6.39
	0.551		20.73	19.75	-4.73
	0.628		22.15	21.68	-2.12
	0.702		23.57	23.31	-1.10
	0.776		24.87	24.94	0.28
	0.851		26.01	25.37	-2.47
	0.925		27.03	27.89	3.18
	1.000	(27.77 deg)	28.57	29.42	2.98
2.0	0.099		10.23	9.04	-11.63
	0.212		12.25	10.94	-10.69
	0.326		14.15	13.07	-7.63
	0.439		16.11	15.21	-5.59
	0.553		17.83	17.65	-1.01
	0.628		19.16	19106	-0.52
	0.703		20.03	20.73	3.49
	0.778		21.06	22.24	5.60
	0.851		21.83	23.90	9.48
	0.926		23.11	24.83	7.44
	1.000	(27.61 deg)	26.10	25.61	-1.88
1.0	0.106		9.49	8.12	-14.44
	0.228		10.99	9.89	-10.01
	0.352		12.53	12.04	-3.91
	0.474		14.41	13.99	-2.91
	0.596		15.72	16.13	2.61
	0.678		16.68	17.63	5.70
	0.758		17.33	18.87	8.89
	0.839		18.25	20.29	11.18
	0.921		19.01	22.07	16.10
	1.000	(25.45 deg)	19.51	22.19	13.47
0	0.103		7.99	5.93	-29.78
	0.228		9.44	7.89	-16.42
	0.353		10.89	9.80	-10.01
	0.475		12.29	11.68	-4.96
	0.597		13.34	13.42	0.60
	0.678		13.72	14.47	5.47
	0.760		13.67	19.48	13.24
	0.839		12.32	16.36	----
	0.920		8.12	17.21	----
	1.000	(25.25 deg)	8.34	17.84	----

Mean % Difference = -1.52
Standard Deviation = -8.92

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 7)

$A = 8.00$	$\Lambda_{c/4} = 12.5$ deg	$X_H = 2.92\ \bar{c}_W$	$Z_H = 1.45\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 30$ deg	$\delta_T = 0$ deg	$\overline{A_c}/A_j = 0.502$

C_{μ_J}	$\alpha_W/\alpha_W\left(C_{L_{aero}}\right)_{max}$	$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.100	8.96	9.68	8.04
	0.213	10.55	11.26	6.73
	0.327	12.70	13.01	2.44
	0.440	14.51	14.88	2.55
	0.552	16.08	16.89	5.04
	0.628	17.22	18.21	5.75
	0.702	18.60	19.68	5.81
	0.777	19.75	20.99	6.28
	0.853	21.08	22.45	6.50
	0.927	22.59	23.77	5.22
	1.000 (27.77 deg)	24.30	24.86	2.30
2.0	0.098	8.03	8.01	-0.25
	0.212	9.69	9.44	-2.58
	0.326	11.01	11.11	0.91
	0.439	12.70	12.90	1.57
	0.553	14.18	14.76	4.09
	0.627	15.34	15.97	4.11
	0.702	16.68	17.26	3.48
	0.777	17.79	18.47	3.82
	0.857	18.78	19.62	4.47
	0.926	19.81	20.80	5.00
	1.000 (27.63 deg)	21.10	21.42	1.52
1.0	0.106	7.63	7.03	-7.86
	0.230	8.71	8.43	-3.21
	0.352	10.18	10.03	-1.47
	0.474	11.42	11.67	2.19
	0.597	12.96	13.35	3.01
	0.677	13.79	14.50	5.15
	0.759	14.76	15.67	6.17
	0.839	15.62	16.68	6.79
	0.921	16.48	17.82	8.13
	1.000 (25.48 deg)	17.31	18.58	7.34
0	0.103	6.44	4.93	-23.95
	0.227	7.58	6.46	-14.53
	0.350	9.02	7.89	-12.53
	0.472	9.99	9.39	-6.11
	0.595	11.02	10.89	-1.18
	0.674	11.77	11.62	-1.27
	0.755	12.06	12.35	2.40
	0.836	12.33	13.21	7.14
	0.916	12.58	13.98	11.18
	1.000 (25.27 deg)	12.46	14.56	16.85

Mean % Difference = 2.07

Standard Deviation = 7.04

Table 2-37. Substantiation Data for Externally Blown Double-Slotted Flap (Sheet 8)

$A = 8.00$	$\Lambda_{c/4} = 12.5$ deg	$X_H = 2.92\ \bar{c}_W$	$Z_H = 0.55\ \bar{c}_W$
$\delta_{LE} = 55$ deg	$\delta_f = 30$ deg	$\delta_T = 0$ deg	$\overline{A_c/A_j} = 0.502$

C_{μ_J}	$\alpha_{\dot{W}}/\alpha_{\dot{W}}\left(C_{L_{aero}}\right)_{max}$		$\epsilon_{measured}$	$\epsilon_{calculated}$	% Difference
4.0	0.100		12.76	11.45	-10.27
	0.213		14.42	13.51	-6.31
	0.327		17.44	15.81	-9.35
	0.440		19.47	18.16	-6.73
	0.552		21.78	20.65	-5.19
	0.628		23.34	22.34	-4.28
	0.702		24.88	24.03	-3.42
	0.777		26.11	25.51	-3.83
	0.853		27.91	27.20	-2.54
	0.927		30.01	28.77	-4.13
	1.000	(27.77 deg)	32.85	29.89	-9.01
2.0	0.098		11.39	9.94	-12.73
	0.212		13.39	11.82	-11.73
	0.326		15.50	13.94	-10.06
	0.439		17.44	16.19	-7.17
	0.553		19.47	18.51	-4.93
	0.627		20.68	19.97	-3.43
	0.702		22.00	21.49	-2.32
	0.777		23.14	22.95	-0.82
	0.857		24.48	24.29	-0.78
	0.926		26.43	25.51	-3.48
	1.000	(27.63 deg)	30.07	26.14	-13.07
1.0	0.106		10.50	8.97	-14.57
	0.230		12.26	10.81	-11.83
	0.357		13.86	12.84	-7.36
	0.474		15.67	14.95	-4.59
	0.597		17.38	17.00	-2.19
	0.677		18.58	18.37	-1.13
	0.759		19.36	19.80	2.27
	0.839		20.25	20.91	3.26
	0.921		21.15	22.21	5.01
	1.000	(25.48 deg)	22.19	23.04	3.83
0	0.103		8.94	6.74	-24.61
	0.227		10.59	8.78	-17.09
	0.350		12.26	10.62	-13.38
	0.472		13.76	12.49	-9.23
	0.595		14.91	14.34	-3.82
	0.674		15.41	15.18	-1.49
	0.755		15.39	16.06	4.35
	0.836		14.05	17.04	----
	0.916		13.21	17.89	----
	1.000	(2[illegible].27 deg)	10.08	18.45	----

Mean % Difference = -5.85
Standard Deviation = 6.25

2.3 SPECIFIC AIRCRAFT CONFIGURATIONS CORRELATION STUDIES

The specific aircraft that were analyzed are listed below:

Group 1 — F-4C, F-106, CV880
Group 2 — A-4D, F-102, AX (Model CV70)
Group 3 — F-101, F-104, X-3
Group 4 — NAVION

The data readily available on some of the configurations were limited, therefore, there are some areas that comparisons are not shown for all configurations. The dynamic derivatives for some configurations are questionable as to whether they are test data or estimated data as they were extracted from reports that did not make that distinction. The data for the F-102 and F-104 extracted from References 3.35 and 3.37, respectively, are the only ones that are known to be dynamically tested.

The flight conditions utilized in the correlation studies for each of the specific aircraft configurations are presented in Table 2-38. The altitudes were selected for each Mach number in order to approximate the wind tunnel test Reynold's number, rigid data conditions or flight test conditions as indicated in the table.

2.3.1 <u>GROUP 1 CONFIGURATIONS (REFERENCES 3.52, 3.53, 3.55)</u>. The comparison between estimated and test data for the F-4C, F-106, and CV880 is presented on Figures 2-25 through 2-48. The results show the same trends that were found in the general correlation studies. In some cases the methodology predicted well for all three configurations while for other derivatives it may predict well for one and not the other. The predicted lift curve slope, sideforce due to sideslip, rolling moment due to roll rate appear reasonable for all configurations. The remainder of the derivatives varied in the prediction accuracy depending on the configuration.

2.3.2 <u>GROUP 2 CONFIGURATIONS (REFERENCES 3.35, 3.46, 3.51)</u>. The estimated data for the AX, A-4D and F-102 are compared with test data in Figures 2-49 through 2-71. The predictability of the methodology is approximately the same as has been recognized throughout the study. Some configurations predict reasonably well for some derivatives and not so good on others. In most instances, there is some configuration that correlates with the test data for a particular derivative. The only derivative that has consistently shown good agreement is the lift curve slope. The spoiler data shown in Figures 2-70 and 2-71 show poor agreement but the magnitude of the derivatives makes it difficult to extract the test data and could result in significant differences.

2.3.3 <u>GROUP 3 CONFIGURATIONS (REFERENCES 3.30, 3.37, 3.45)</u>. The correlation results for the X-3, F-101, and F-104 are presented in Figures 2-72 through 2-84 and the same conclusion can be made about this data package as for the previous ones.

2.3.4 GROUP 4 CONFIGURATION (REFERENCE 3.56). The comparison of the NAVION aircraft characteristics estimated by the Flying Qualities Program, the author of Reference 3.56 utilizing DATCOM methods and data extracted from flight test presented in Table 2-39. The data computed by the FQP Program agrees reasonably well with the other data, except for the rudder effectiveness.

TABLE 2-38

FLIGHT CONDITIONS

CONFIG.	Ref.	M	h(ft)	Basis
CV-880	3.52	0.2 - 0.95	60000.	Rigid Data
F-4C	3.55	0.2 - 2.0	55000.	Rigid Data
F-106	3.53	0.2 - 2.0	60000.	Rigid Data
AX	3.46	0.26	69500.	$R_n = 1.1 \times 10^6$
		0.50	61000.	$= 3.2 \times 10^6$
		0.60	65000.	
		0.65	66500.	
		0.70	68000.	
		0.80	70500.	
A-4D	3.51	0.6 - 1.0	35000.	Rigid Data
F-102	3.35	0.25	67000	$R_n = 2.75 \times 10^6$
		0.60	96000.	$= 1.50 \times 10^6$
		0.85	104000.	
		0.92	105000.	
		0.94	106000.	
X-3	3.30, 3.41	0.20	62800.	$R_n = 2.0 \times 10^6$
	3.42, 3.43	0.25	65500.	$= 2.12 \times 10^6$
		0.40	67000.	$= 3.2 \times 10^6$
		0.60	69000.	$= 4.25 \times 10^6$
		0.70	72000.	$= 4.55 \times 10^6$
		0.80	73500.	$= 4.7 \times 10^6$
		0.90	75000.	$= 4.9 \times 10^6$
		0.925	75500.	$= 4.92 \times 10^6$
F-101	3.45	0.60	73000.	$R_n = 1.5 \times 10^6$
		0.80	74562.	$= 1.82 \times 10^6$
		0.85	74953.	$= 1.88 \times 10^6$
		0.90	75343.	$= 1.96 \times 10^6$
		0.92	75500.	$= 2.0 \times 10^6$
F-104	3.37, 3.51	0.25	67500.	$R_n = 1.5 \times 10^6$
	6.4, 6.5	0.80	83000.	$= 2.0 \times 10^6$
		0.90	85000.	$= 2.3 \times 10^6$
		0.95	82000.	$= 2.7 \times 10^6$
		1.00	82500.	$= 2.8 \times 10^6$
		1.06	83500.	$= 2.81 \times 10^6$
		1.82	109000.	$= 1.38 \times 10^6$
		2.01	117000.	$= 1.02 \times 10^6$
NAVION	3.56	.22	5000.	Flight Test

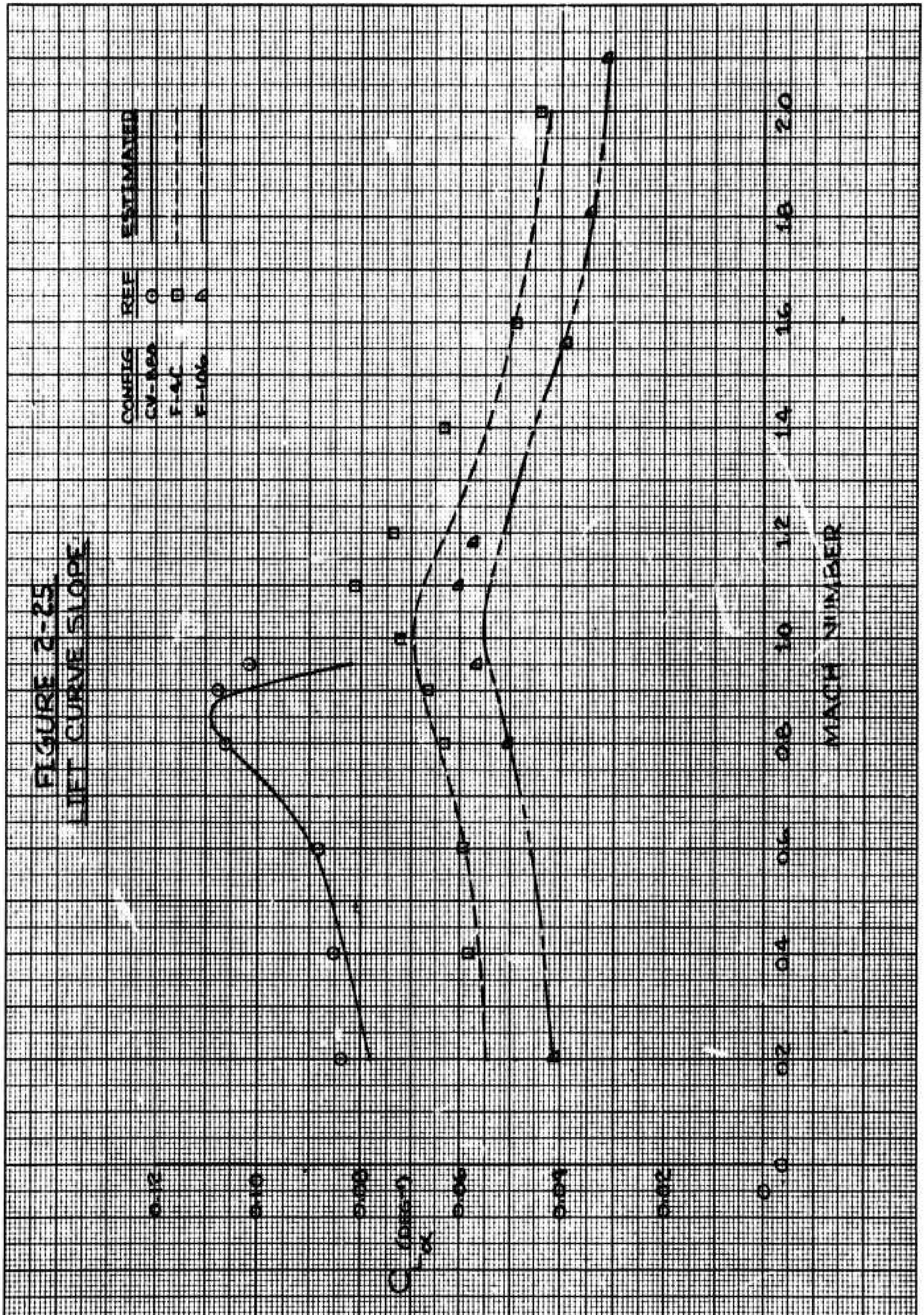


FIGURE 2-25
LIFT CURVE SLOPE
CONFIG REF ESTIMATED
CV-880
F-4C
F-106
C_{L_α} (DEG^{-1})
0.12
0.10
0.08
0.06
0.04
0.02
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

FIGURE 2-26

ZERO LIFT ANGLE-OF ATTACK

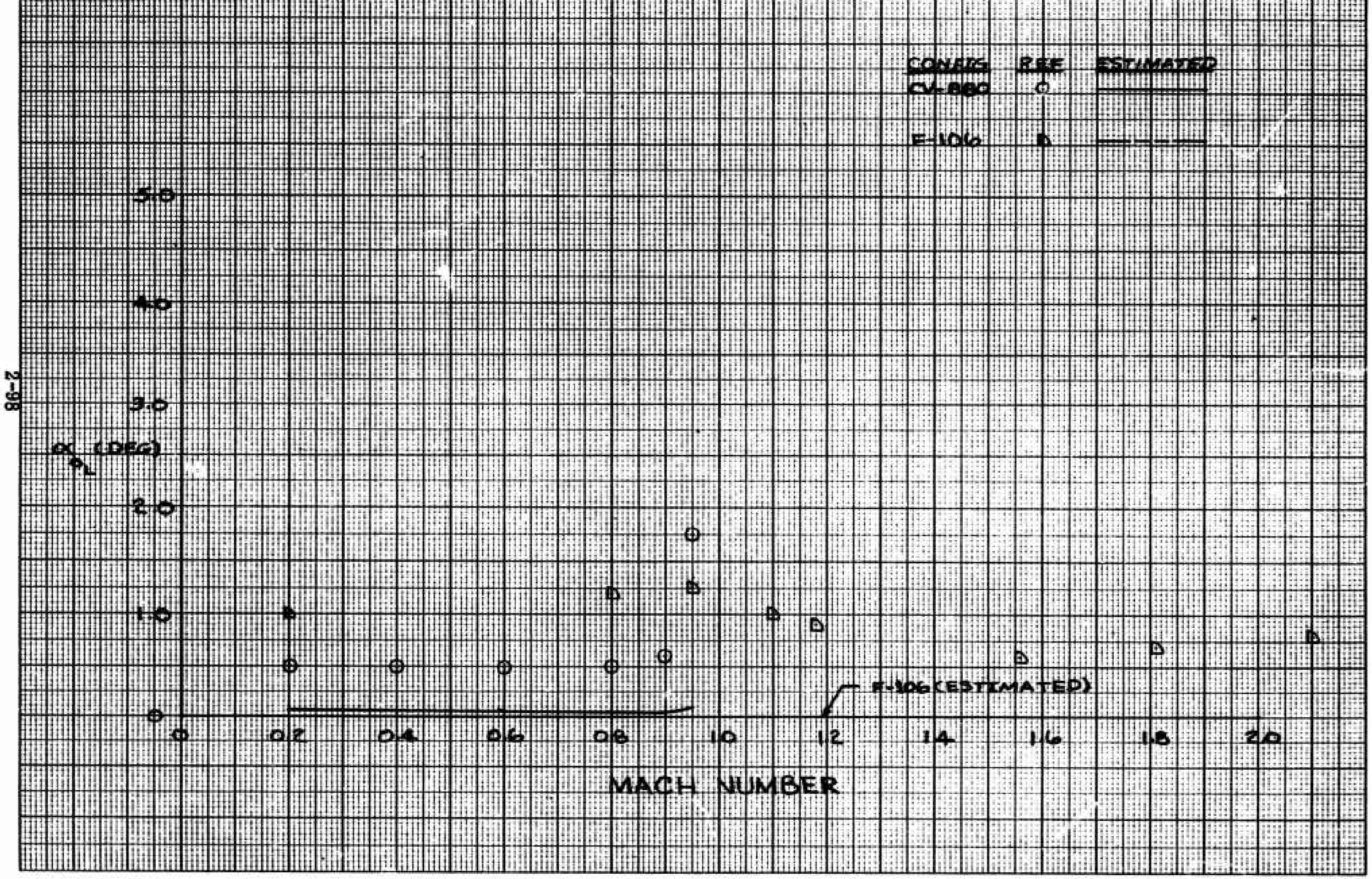
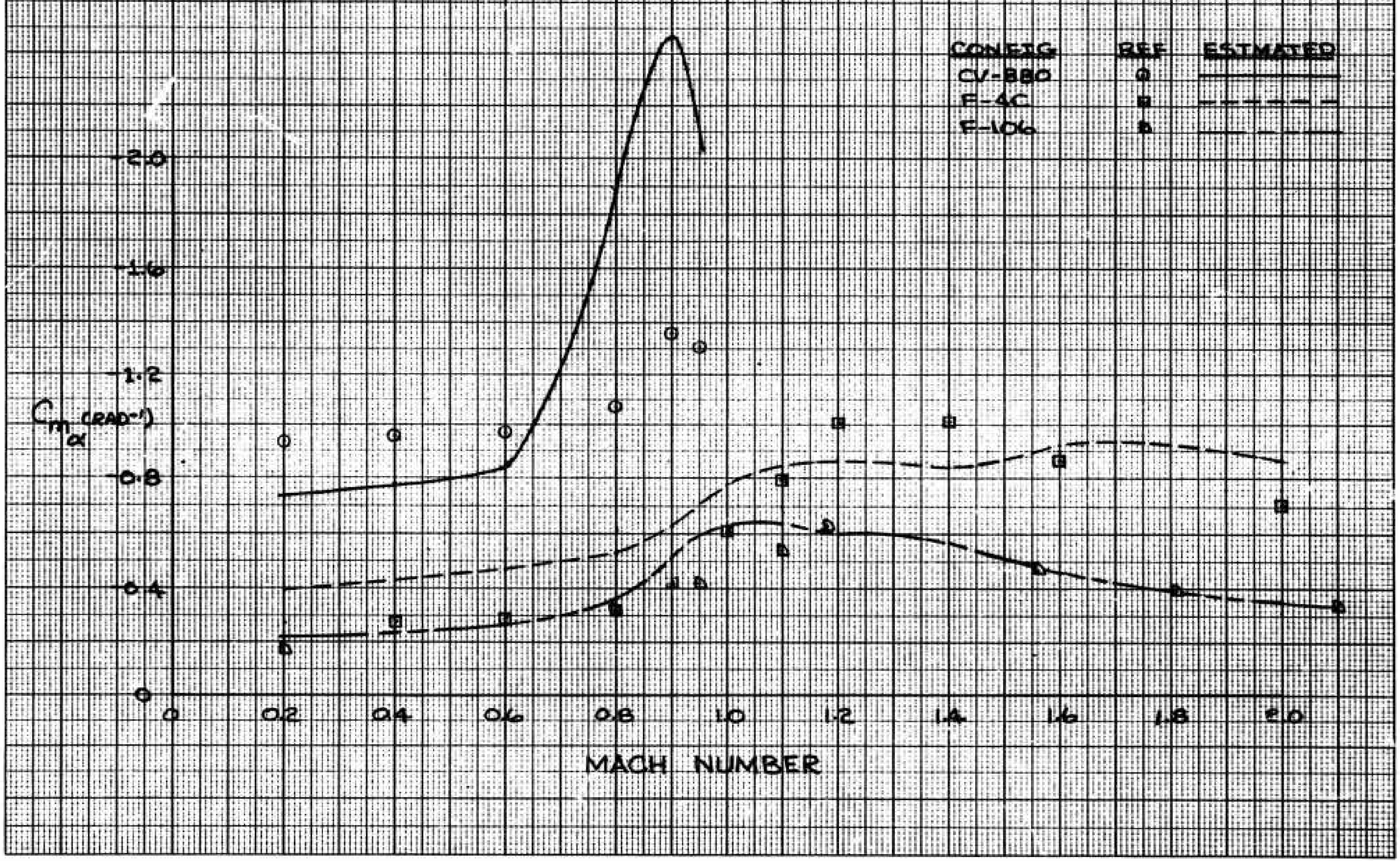


FIGURE 2-27

PITCHING MOMENT CURVE SLOPE



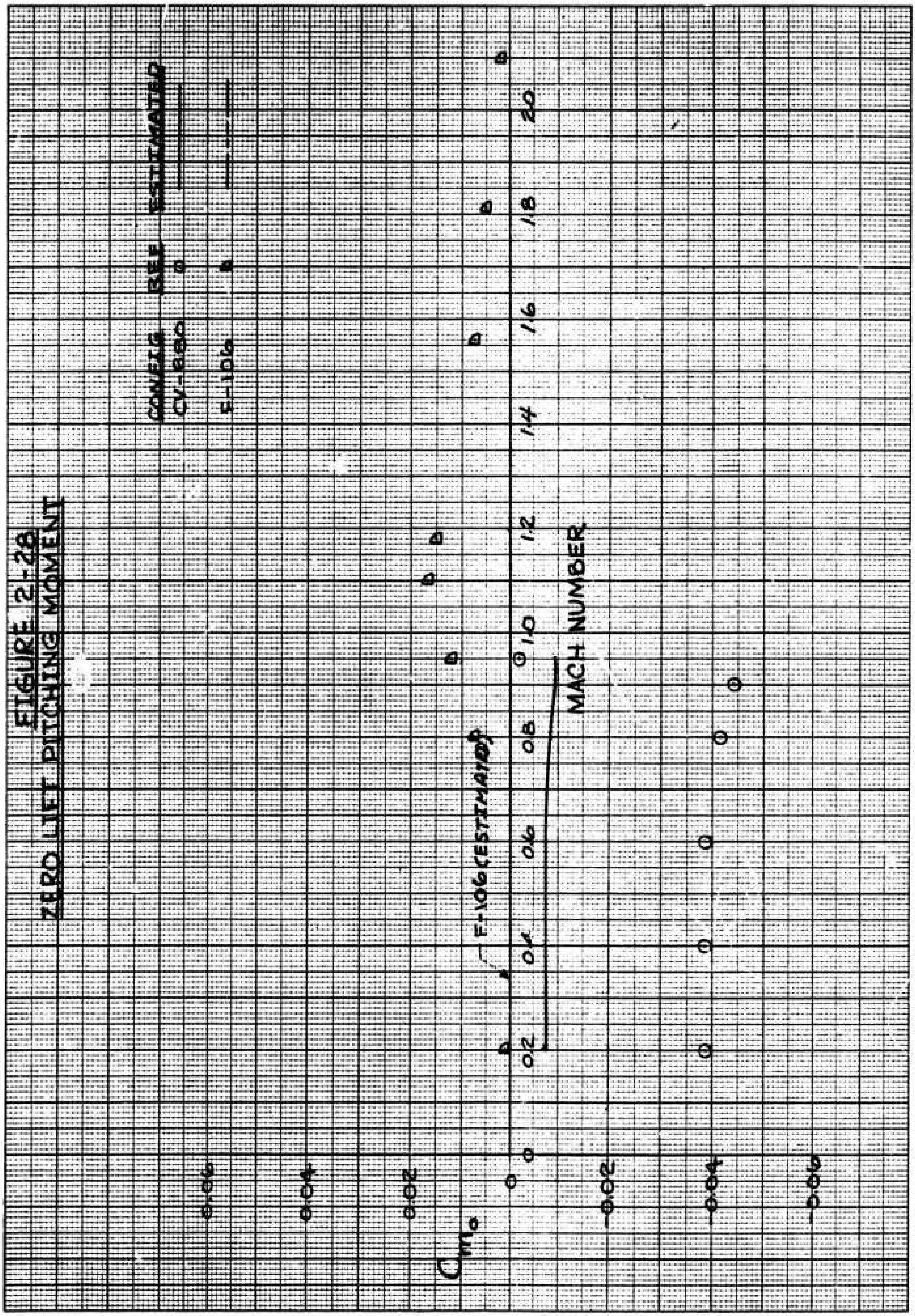


FIGURE 2-28
ZERO LIFT PITCHING MOMENT
CONFIG
CV-880
F-106
REF
ESTIMATED
F-106 (ESTIMATED)
MACH NUMBER
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
C_{m_0}
0.06
0.04
0.02
0
-0.02
-0.04
-0.06

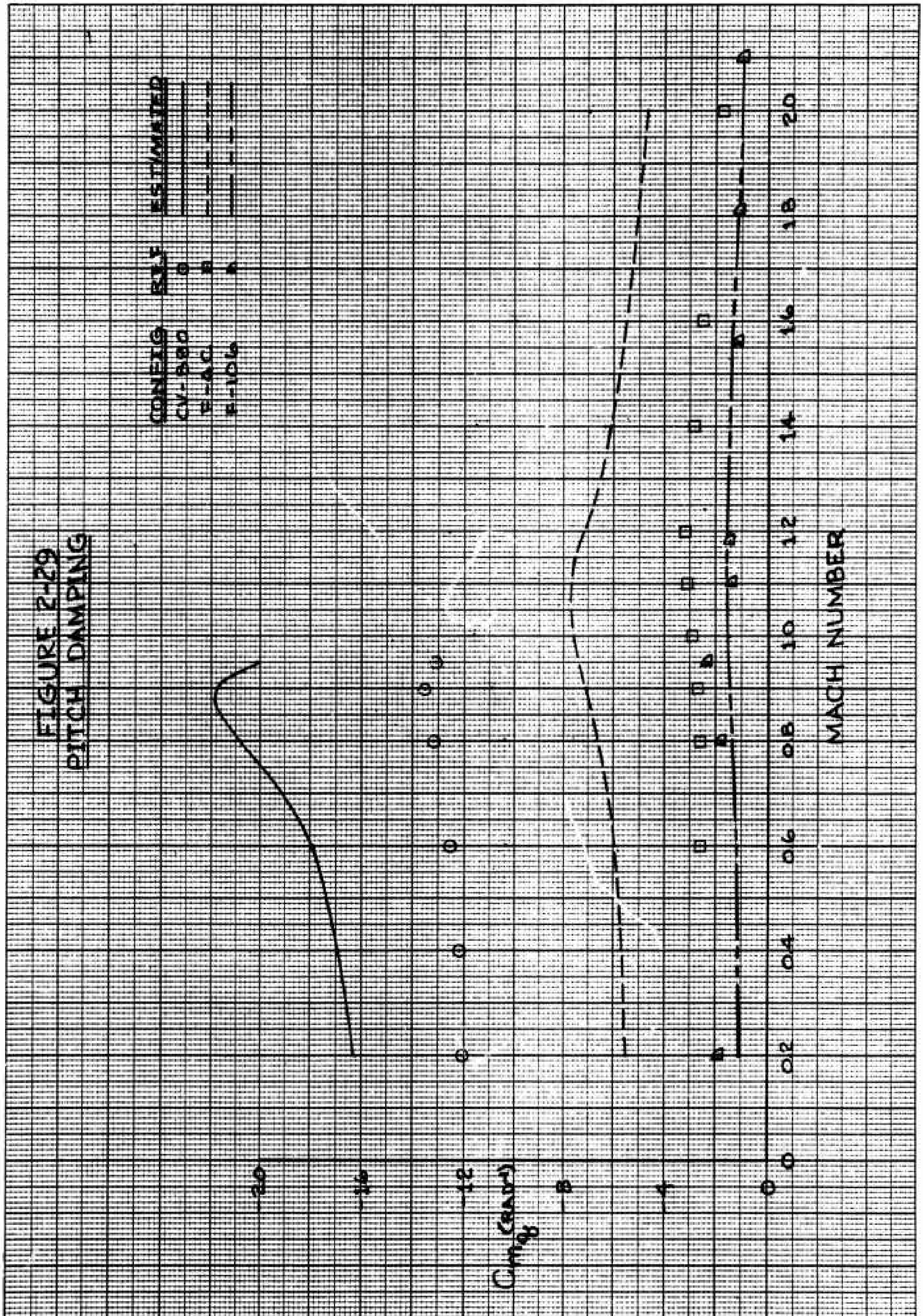
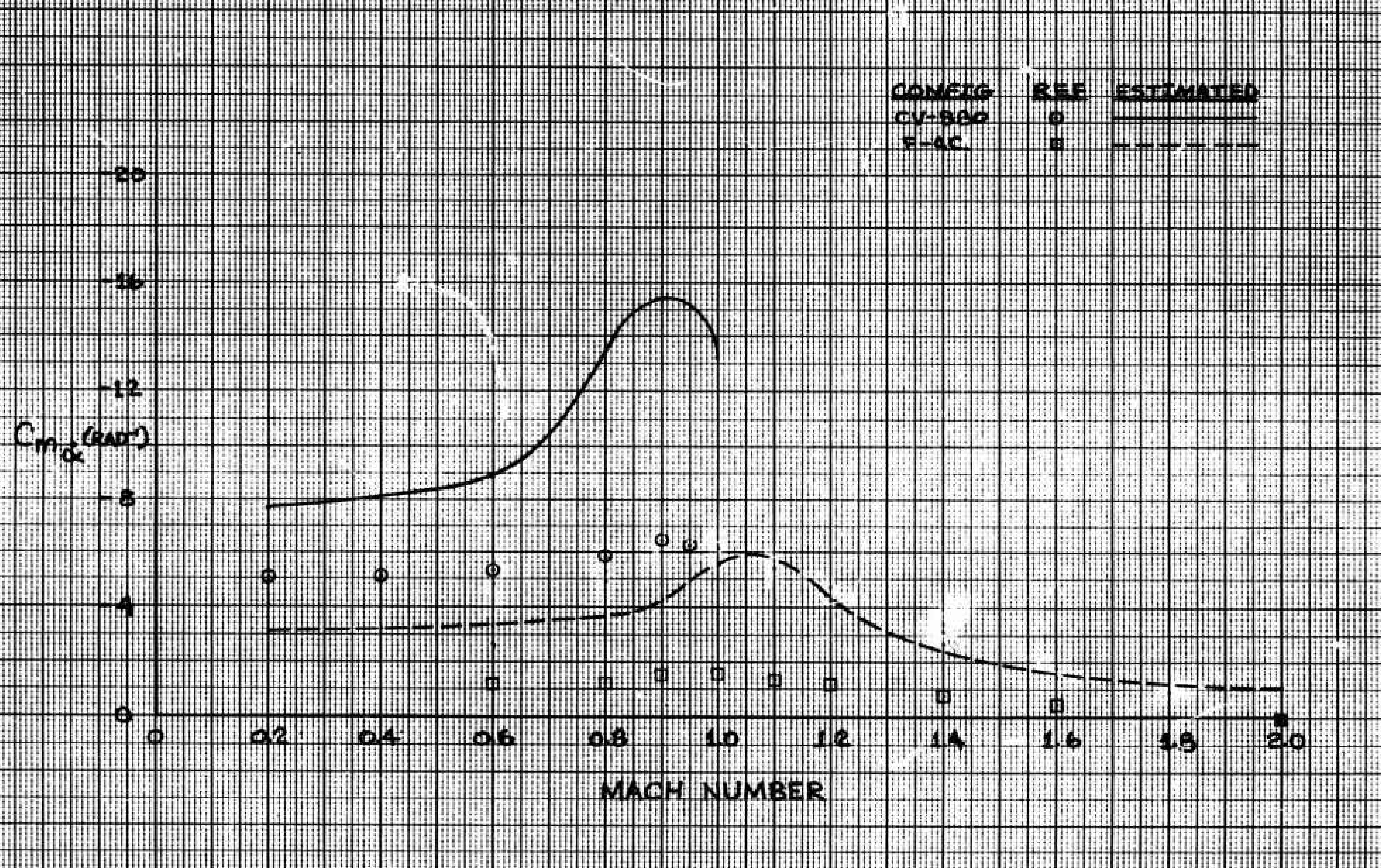


FIGURE 2-29
PITCH DAMPING

FIGURE 2-30

PITCHING MOMENT DUE TO ANGLE-OF-ATTACK RATE



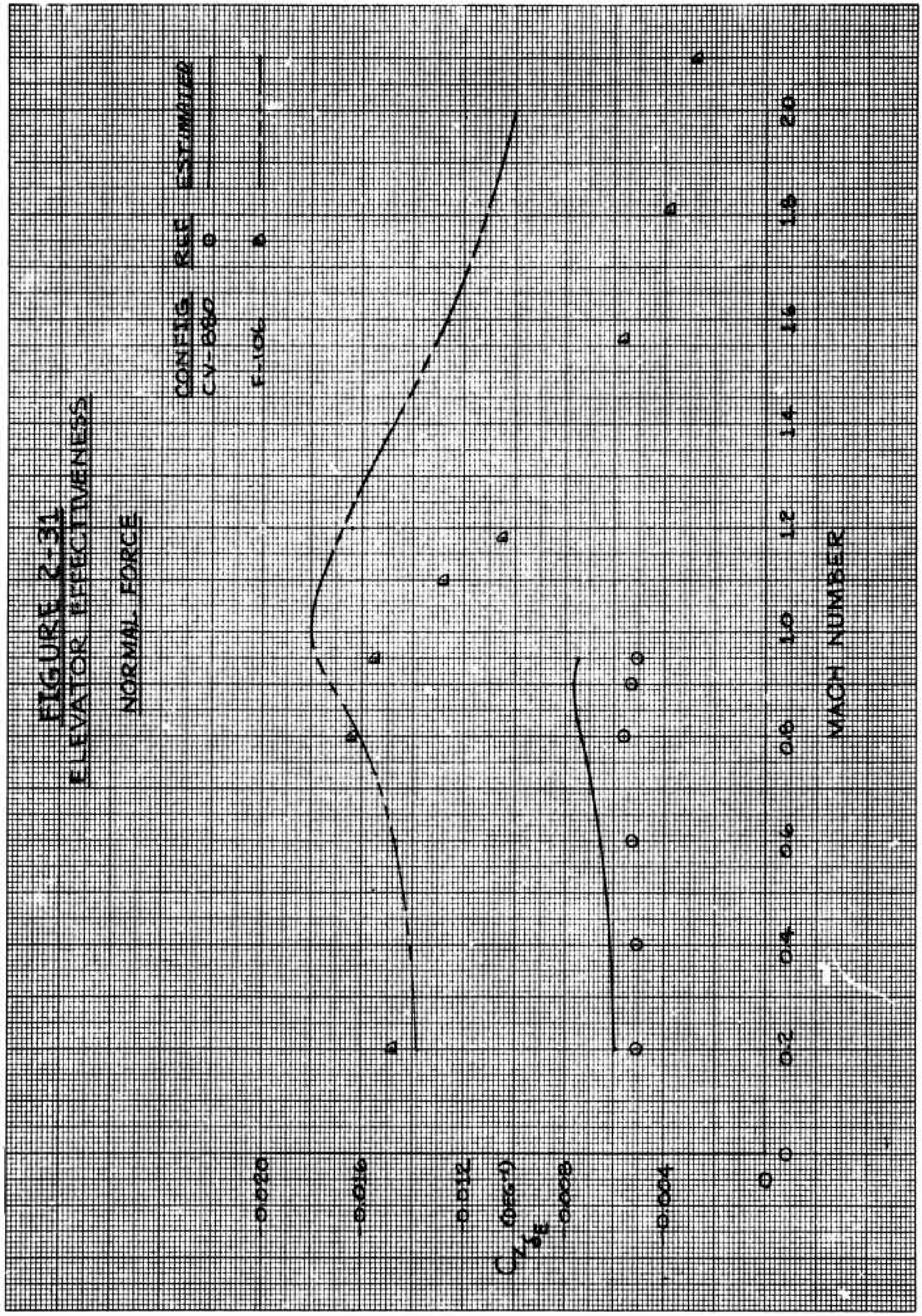


FIGURE 2-31
ELEVATOR EFFECTIVENESS
NORMAL FORCE
CONFIG.
REF.
ESTIMATED
CV-880
F-106
$C_{N_{\delta_E}}$ (DEG⁻¹)
-0.020
-0.016
-0.012
-0.008
-0.004
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

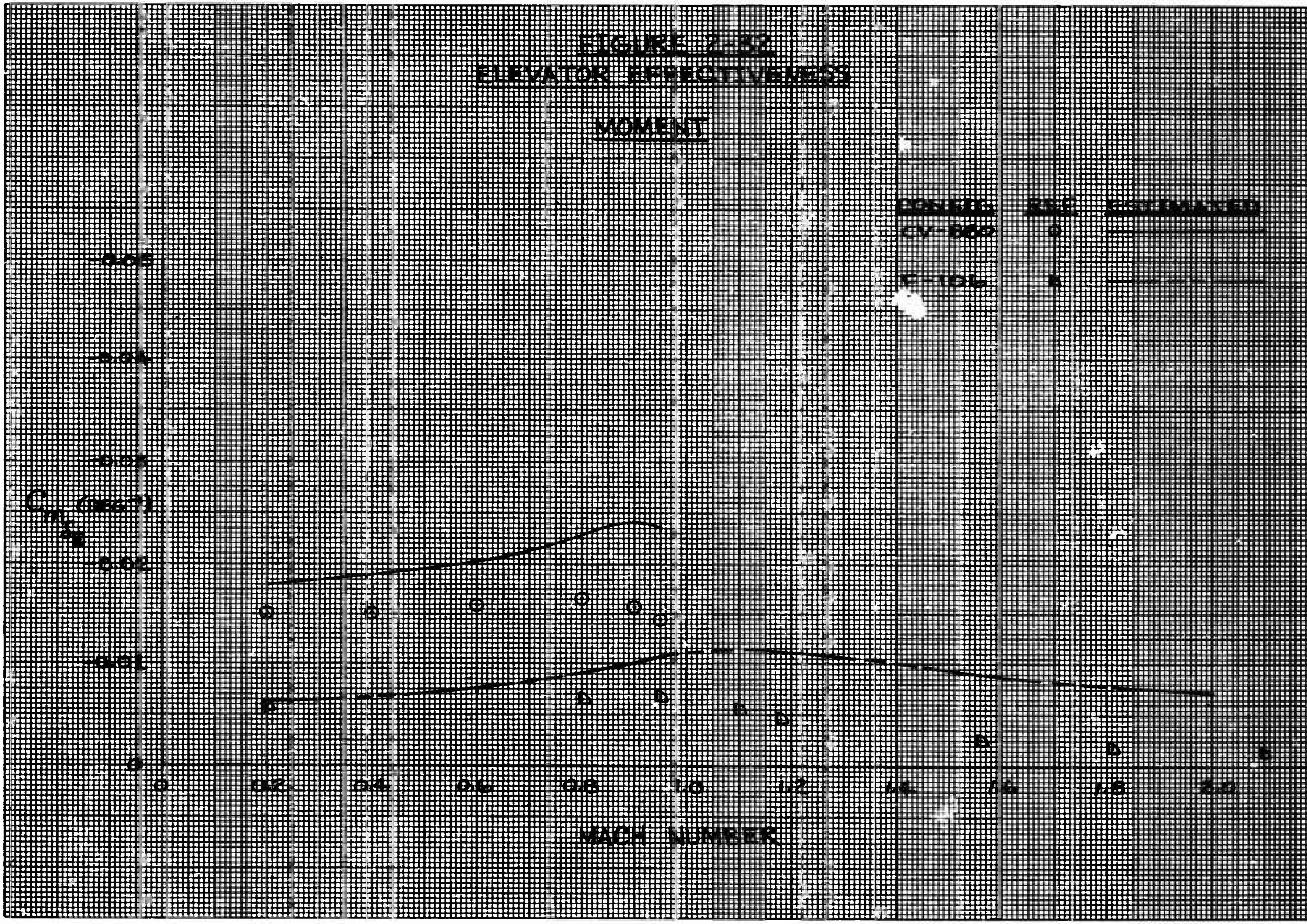


FIGURE 2-32
ELEVATOR EFFECTIVENESS
MOMENT
CONFIG. REF. ESTIMATED
CV-880
F-106
-0.05
-0.04
-0.03
-0.02
-0.01
0
$C_{m_{\delta_e}}$ (DEG^{-1})
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

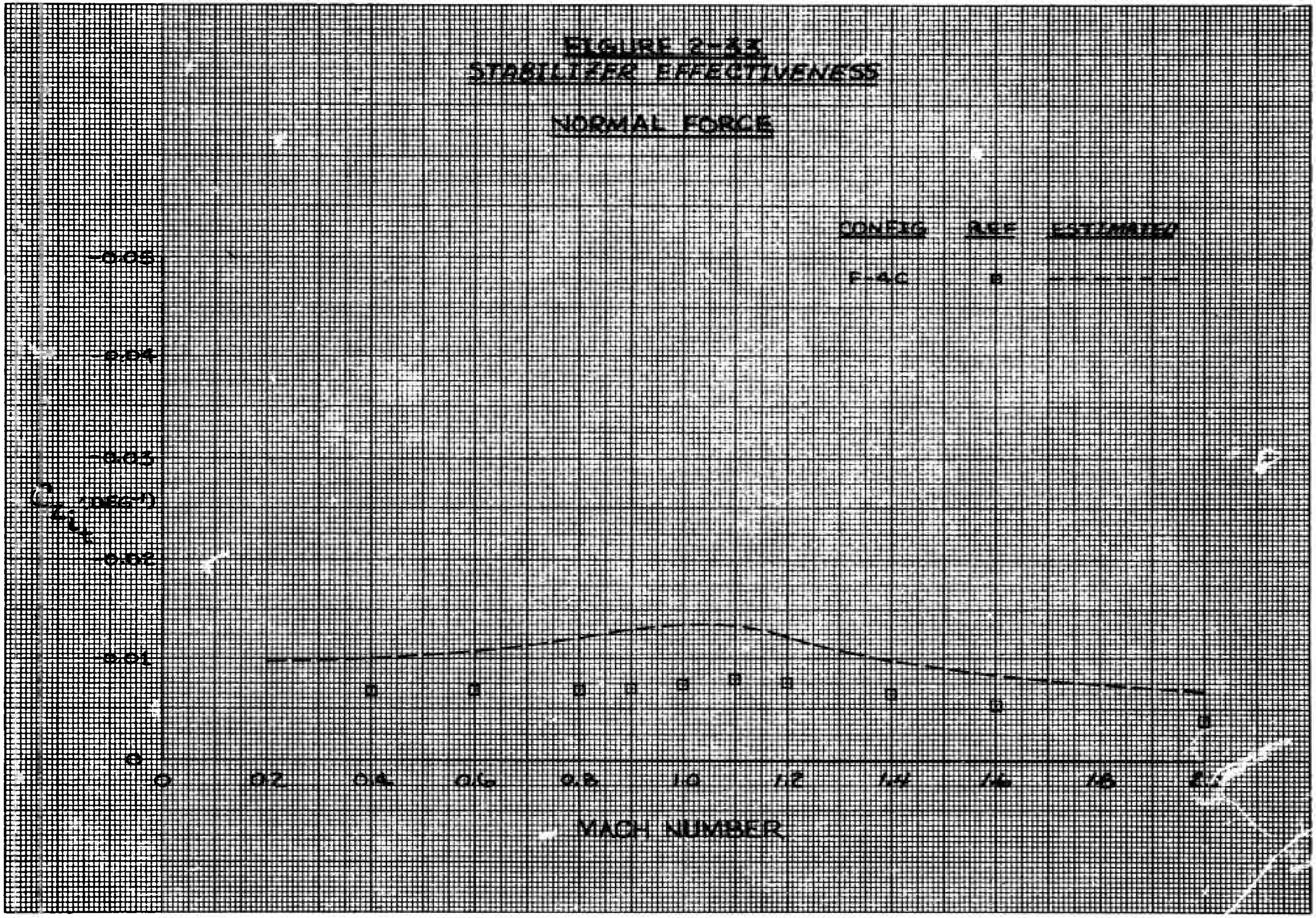


FIGURE 2-33
STABILIZER EFFECTIVENESS
NORMAL FORCE
CONFIG REF ESTIMATED
F-4C
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
MACH NUMBER

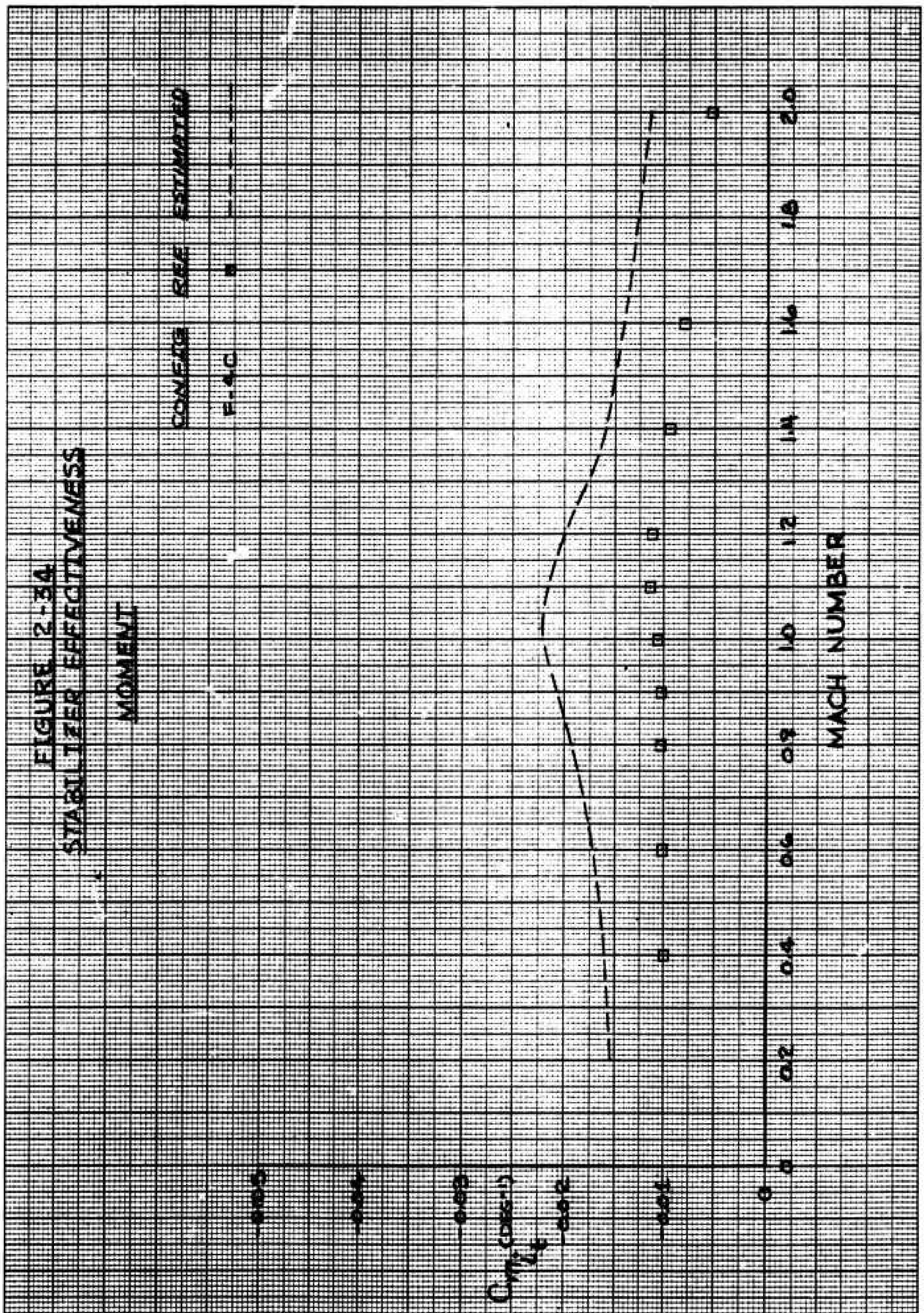
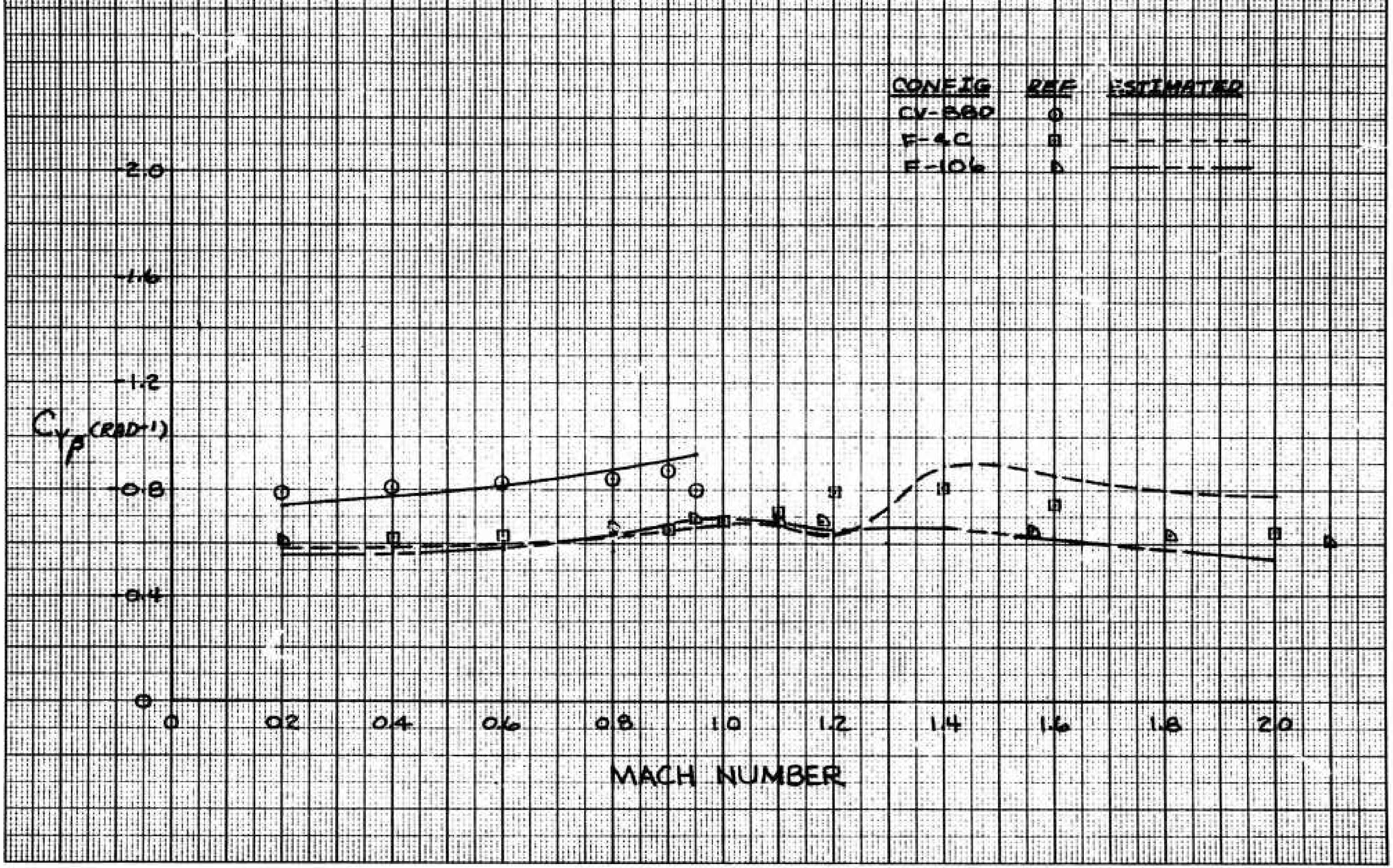


FIGURE 2-34
STABILIZER EFFECTIVENESS
MOMENT
CONFIG REF ESTIMATED
F-4C
$C_{m_{i_t}}$ (DEG⁻¹)
-0.05
-0.04
-0.03
-0.02
-0.01
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

FIGURE 2-35

SIDE FORCE DUE TO SIDESLIP



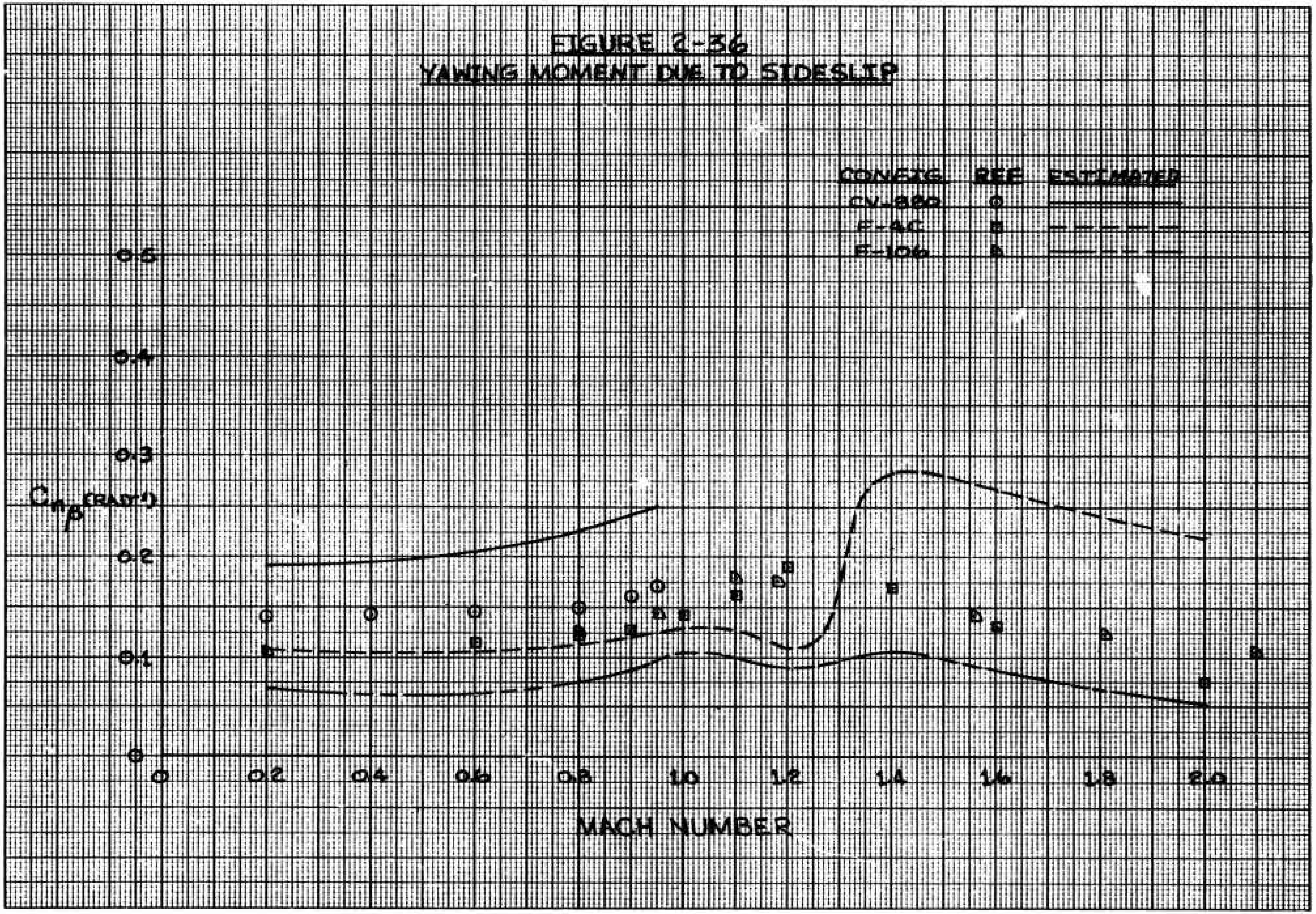


FIGURE 2-36
YAWING MOMENT DUE TO SIDESLIP

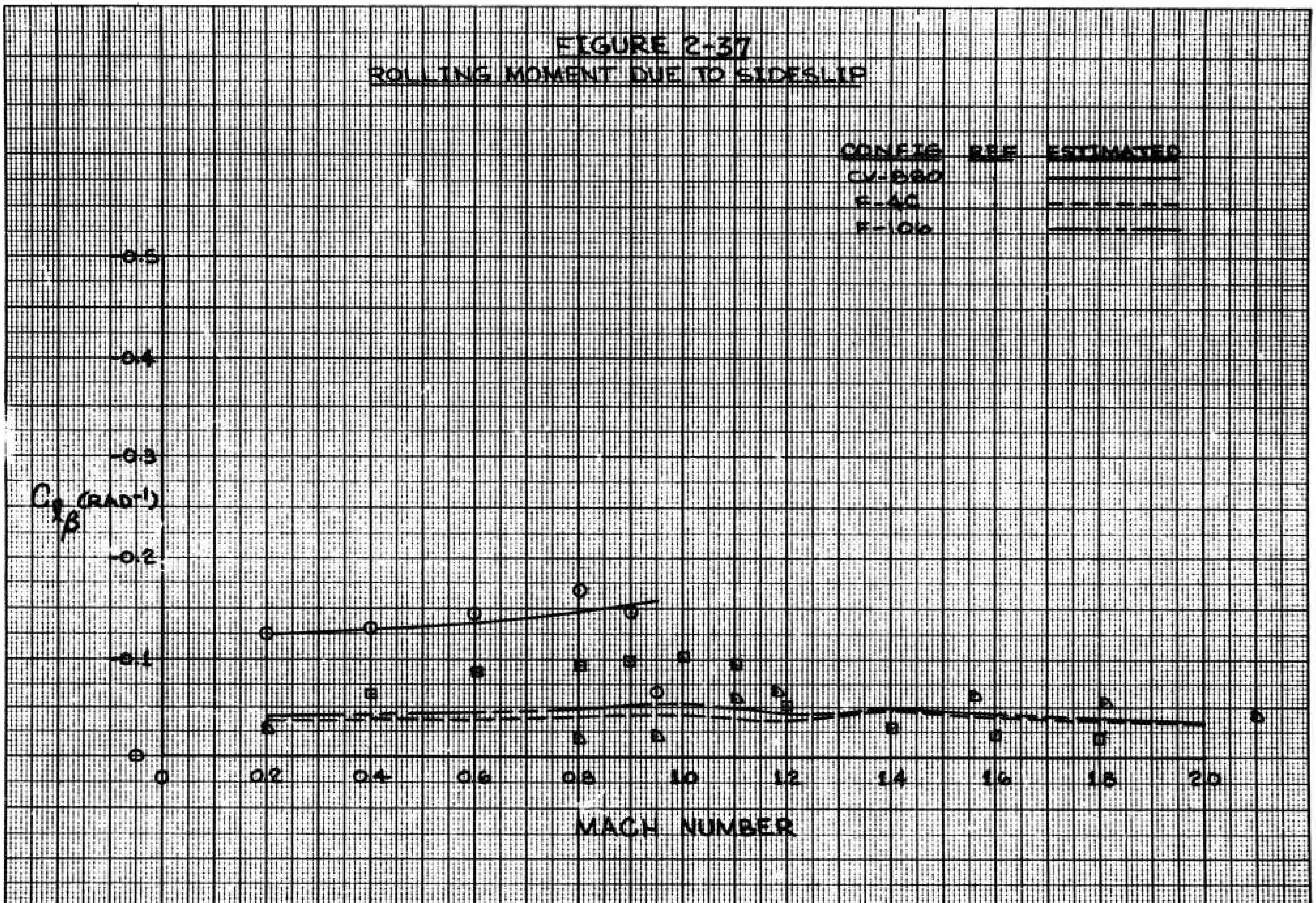


FIGURE 2-37
ROLLING MOMENT DUE TO SIDESLIP

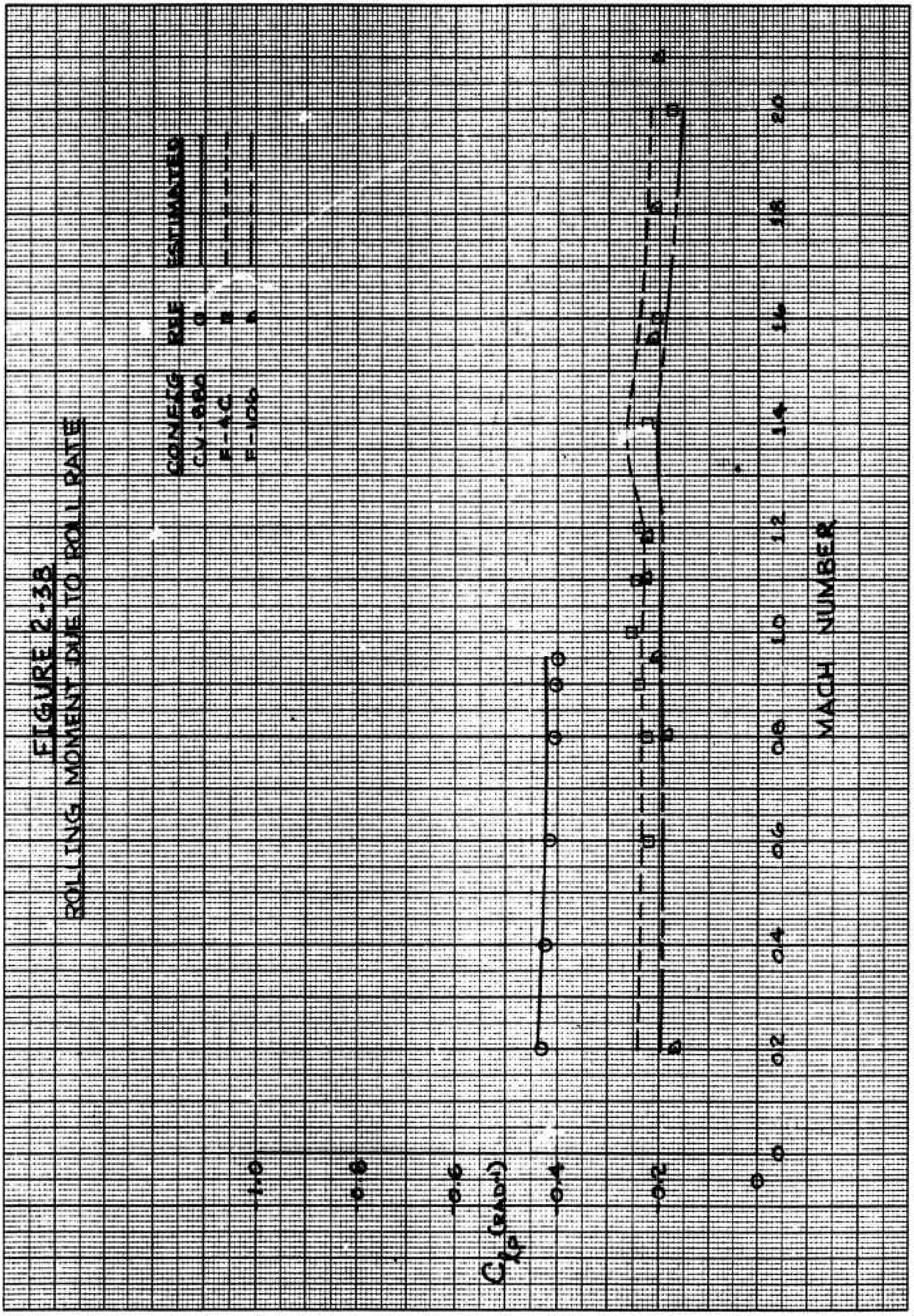


FIGURE 2-38
ROLLING MOMENT DUE TO ROLL RATE
CONFIG
REF
ESTIMATED
CV-880
F-4C
F-106
C_{l_p} (RAD⁻¹)
-1.0
-0.8
-0.6
-0.4
-0.2
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

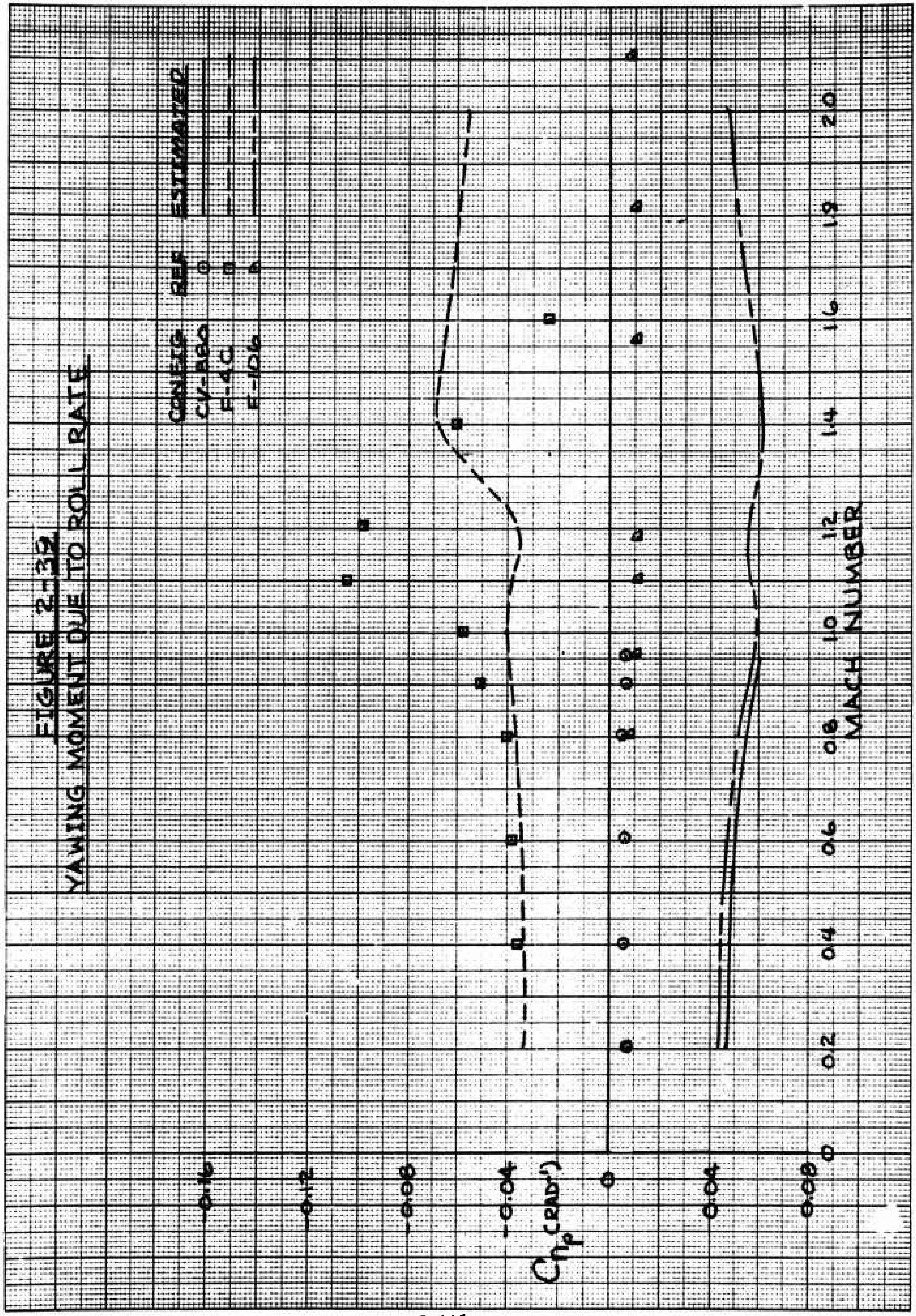
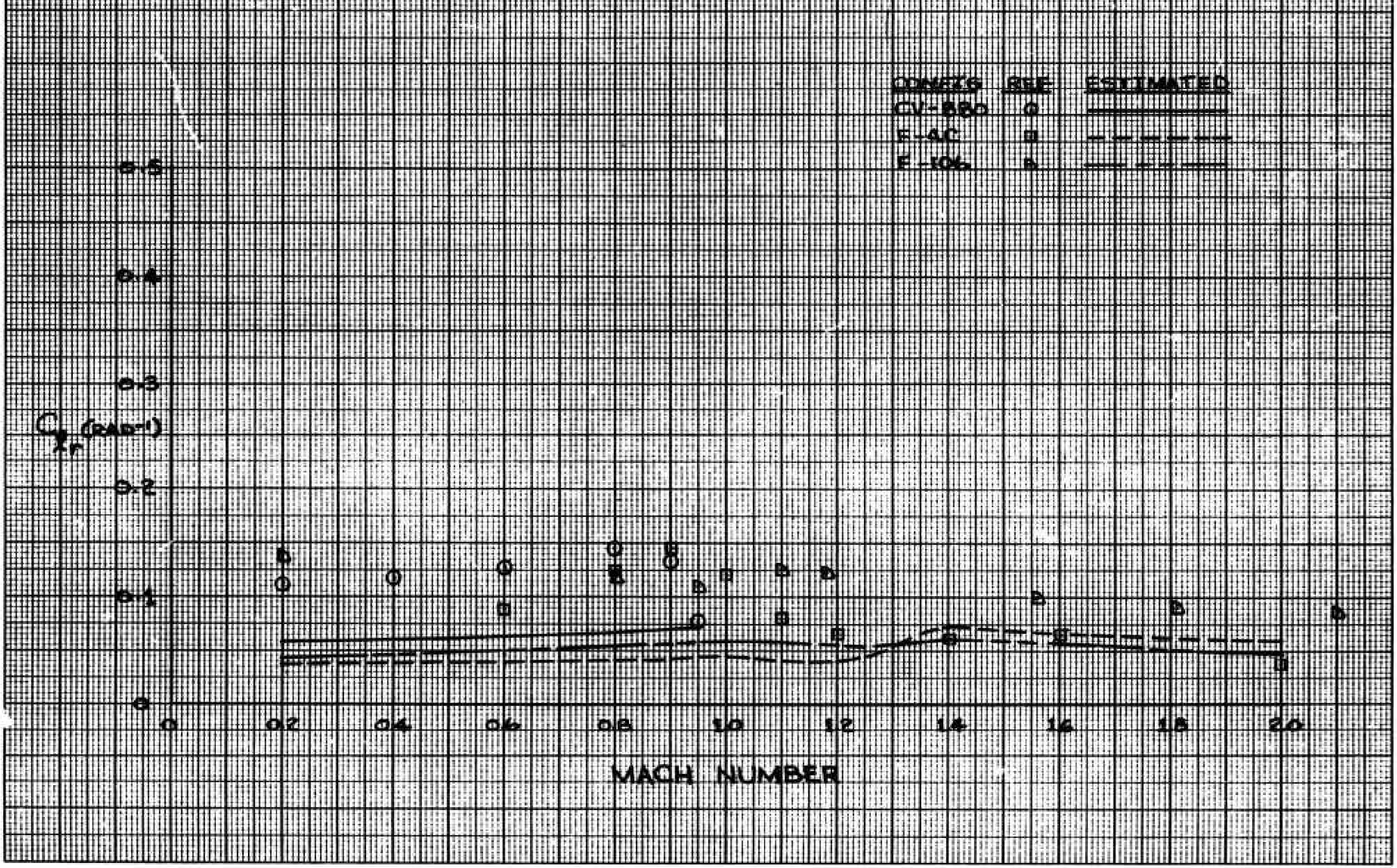


FIGURE 2-32
YAWING MOMENT DUE TO ROLL RATE
CONFIG REF ESTIMATED
CV-880
F-4C
F-106
C_{n_p} (RAD^{-1})
-0.16
-0.12
-0.08
-0.04
0
0.04
0.08
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

FIGURE 2-40

ROLLING MOMENT DUE TO YAW RATE



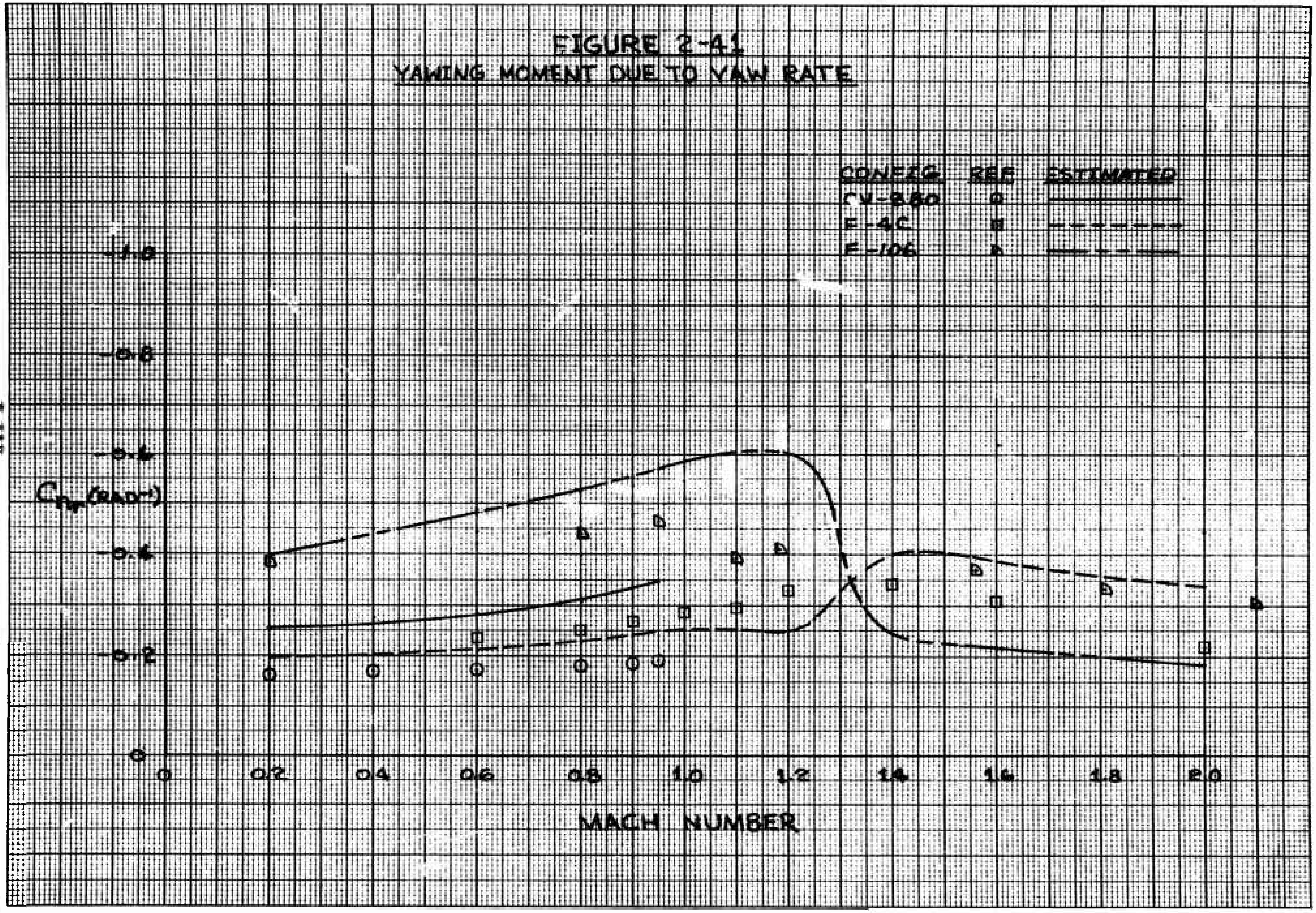


FIGURE 2-41
YAWING MOMENT DUE TO YAW RATE
CONFIG. REF. ESTIMATED
CV-880
F-4C
F-106
-1.0
-0.8
-0.6
-0.4
-0.2
0
C_{n_r} (RAD⁻¹)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

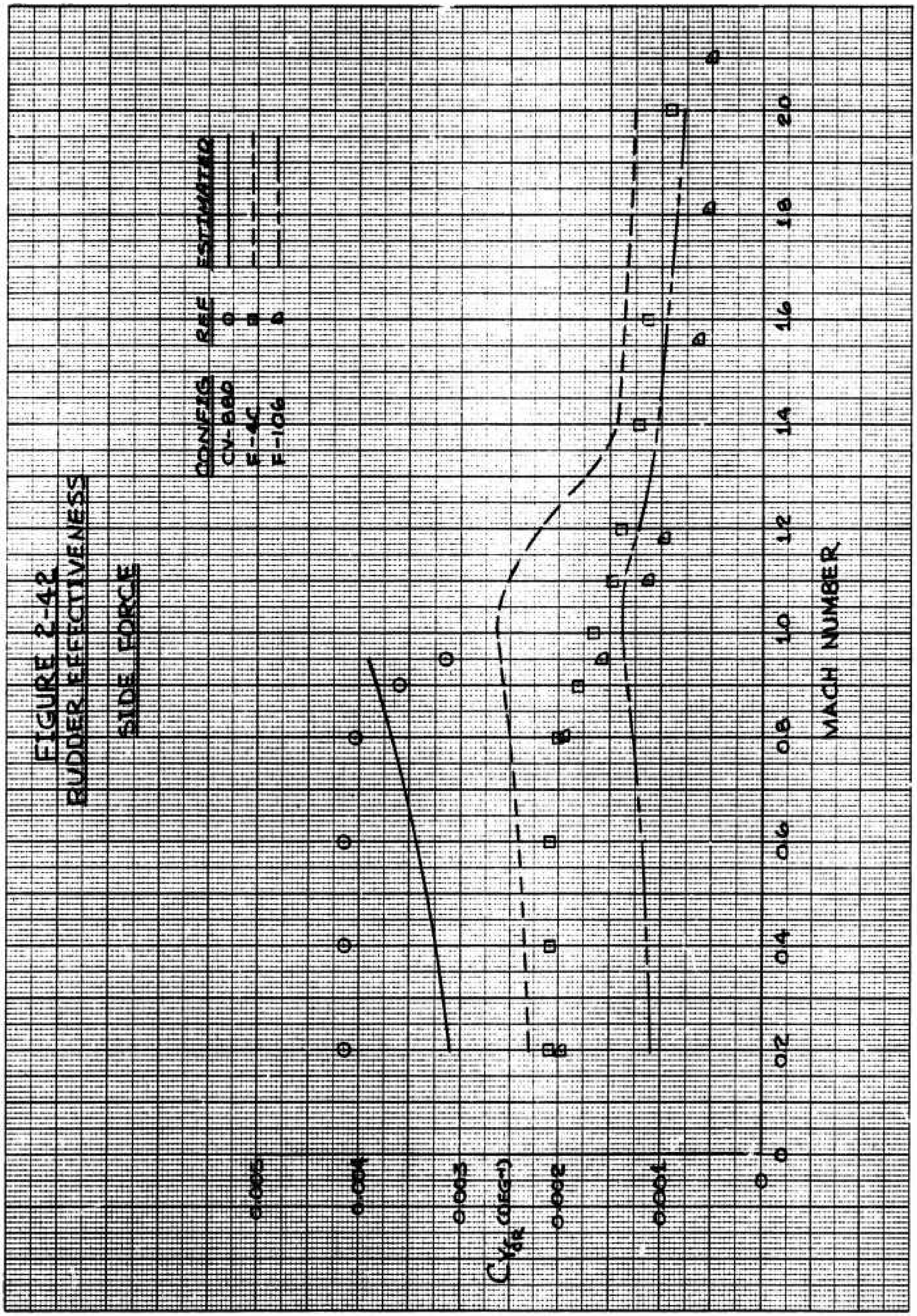


FIGURE 2-42
RUDDER EFFECTIVENESS
SIDE FORCE
CONFIG
CV-880
F-4C
F-106
REF
ESTIMATED
MACH NUMBER
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
0.005
0.004
0.003
0.002
0.001
0
$C_{Y_{\delta R}}$ (DEG⁻¹)

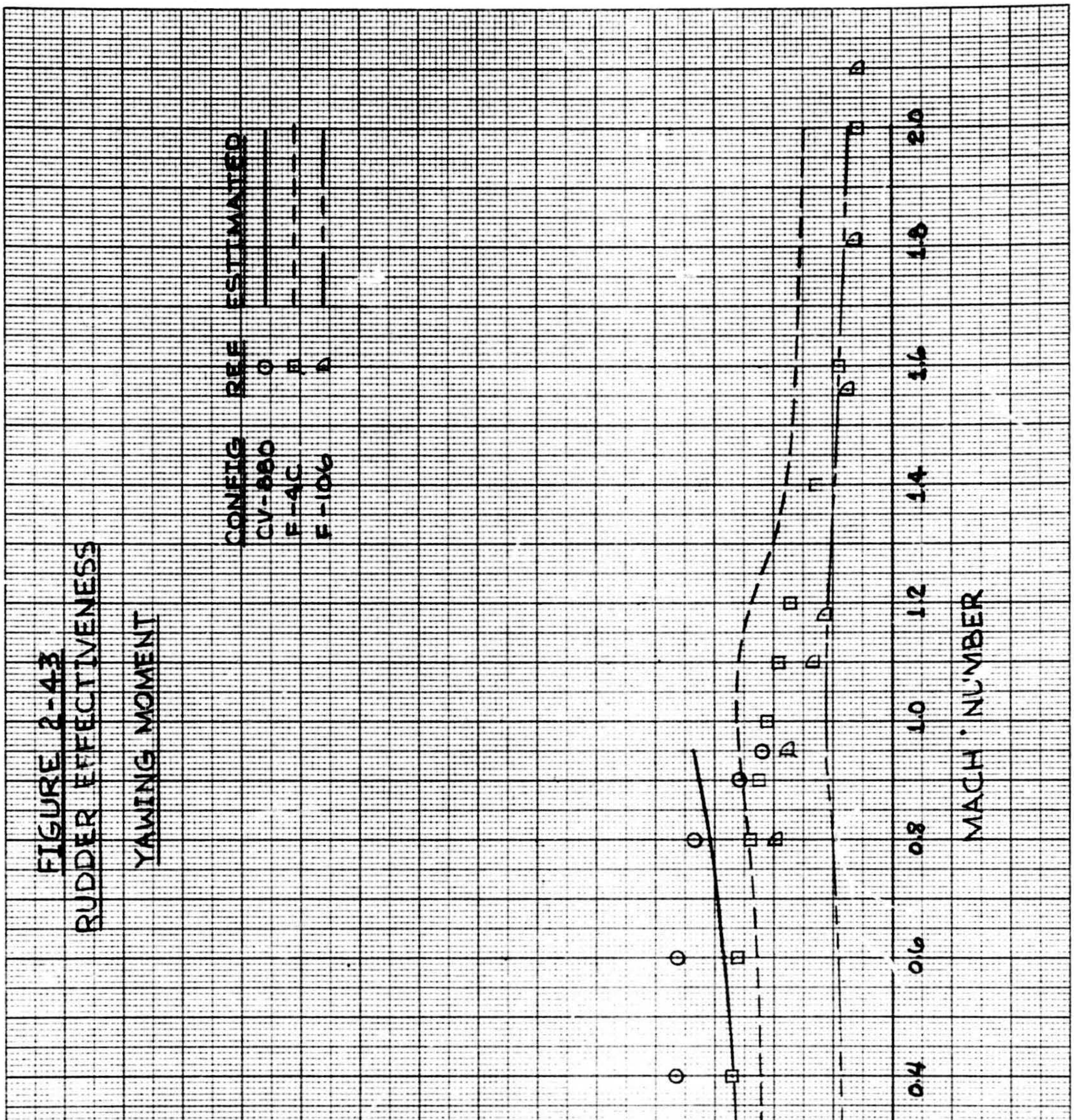


FIGURE 2-43
RUDDER EFFECTIVENESS
YAWING MOMENT
CONFIG REF ESTIMATED
CV-880
F-4C
F-106
$C_{n_{\delta_R}}$ (DEG⁻¹)
-0.005
-0.004
-0.003
-0.002
-0.001
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

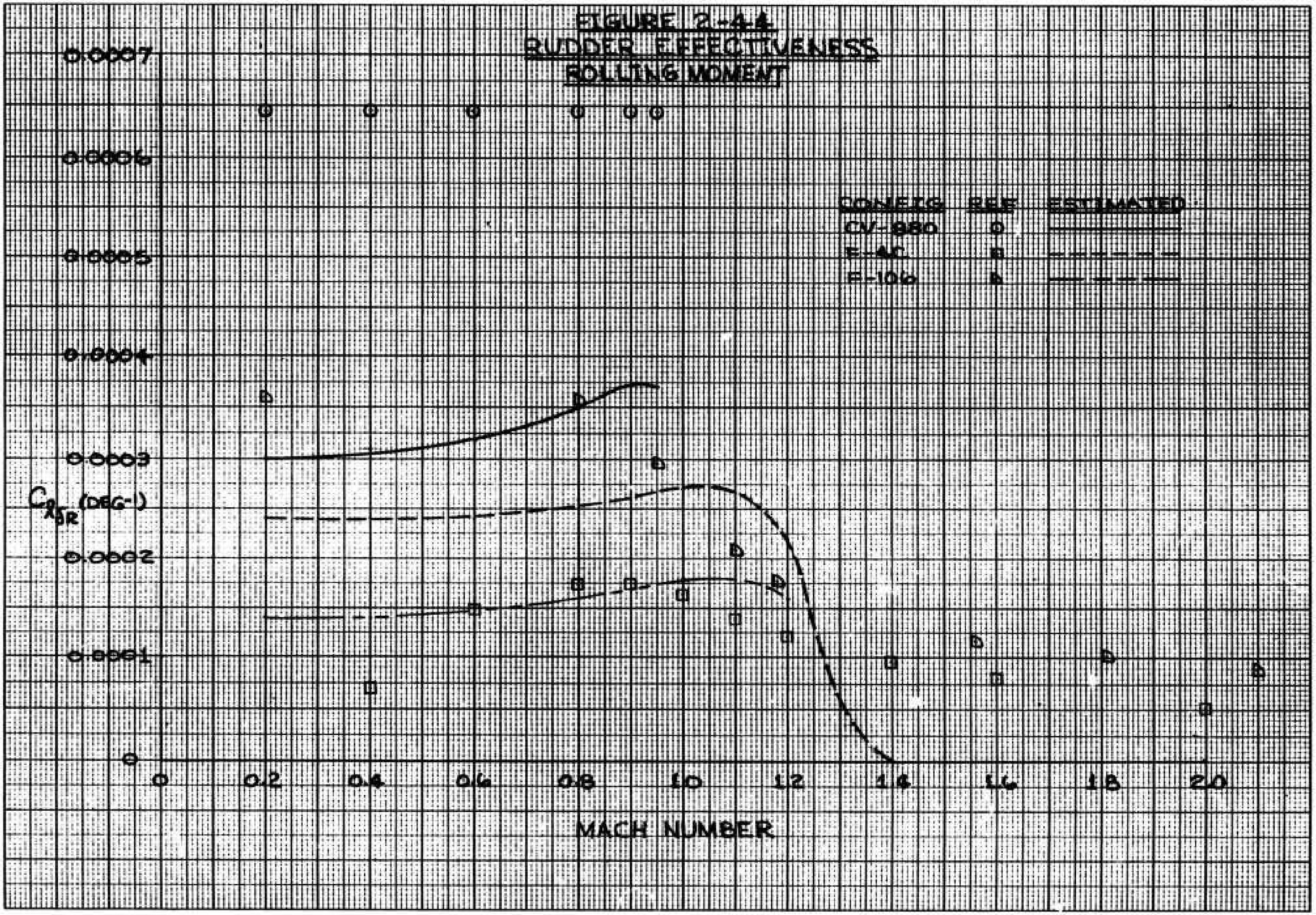
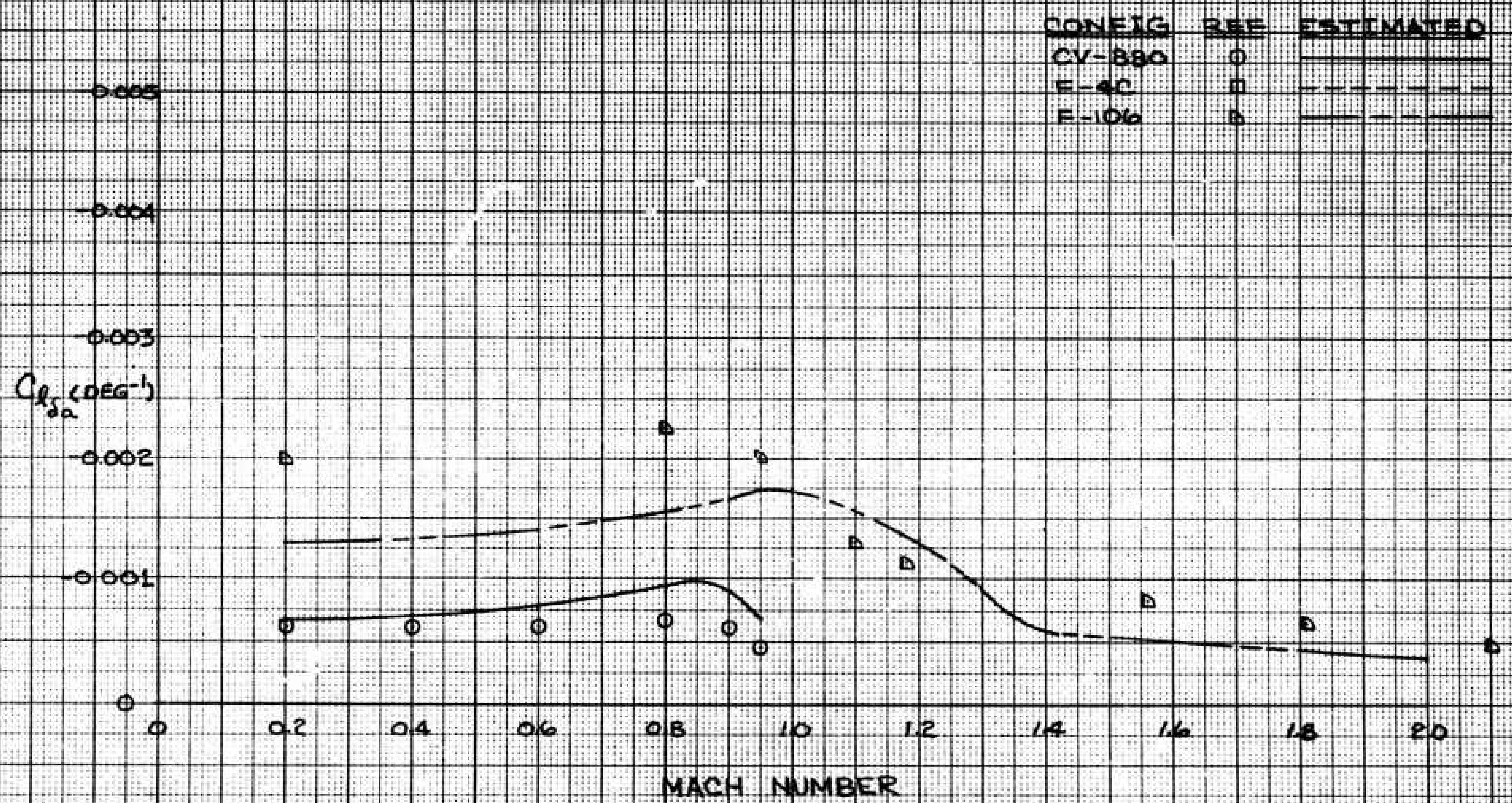


FIGURE 2-44
RUDDER EFFECTIVENESS
ROLLING MOMENT
CONFIG. REF ESTIMATED
CV-880
F-4C
F-106
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
$C_{\ell_{\delta R}}$ (DEG-1)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

FIGURE 2-45
AILERON EFFECTIVENESS

ROLLING MOMENT



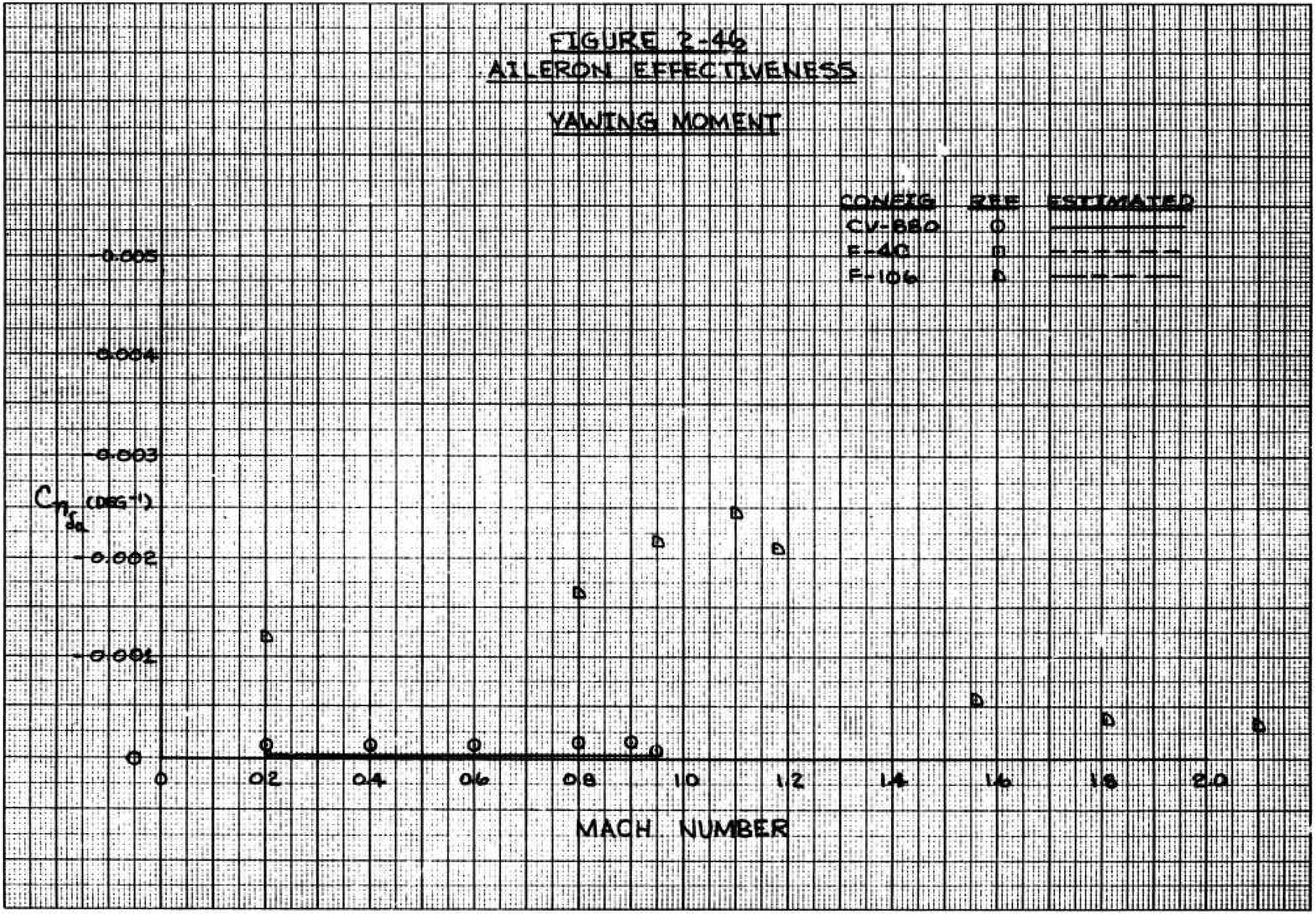


FIGURE 2-46
AILERON EFFECTIVENESS
YAWING MOMENT

FIGURE 2-47
SPOILER EFFECTIVENESS

ROLLING MOMENT

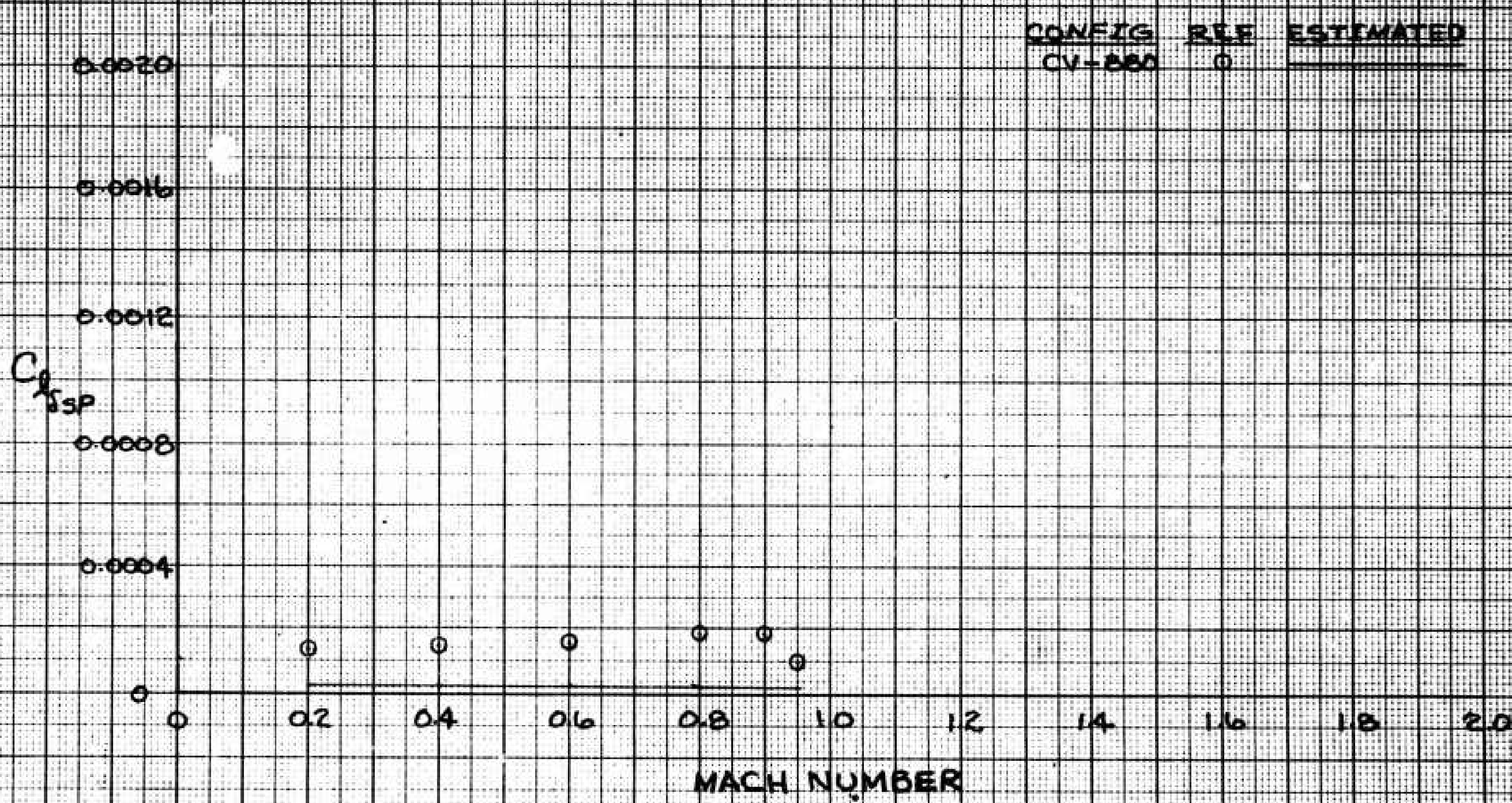
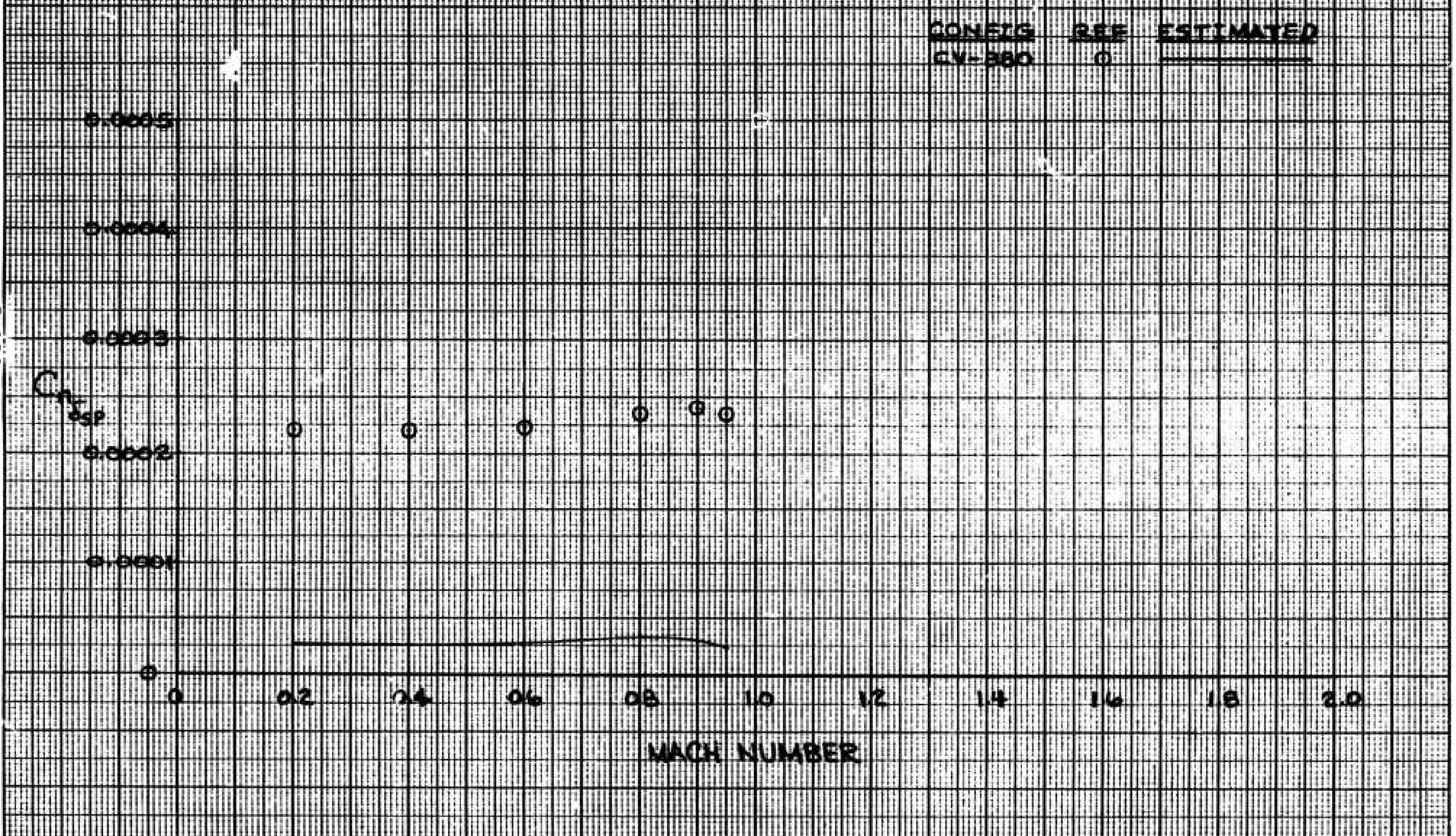


FIGURE 2-48
SPOILER EFFECTIVENESS

YAWING MOMENT



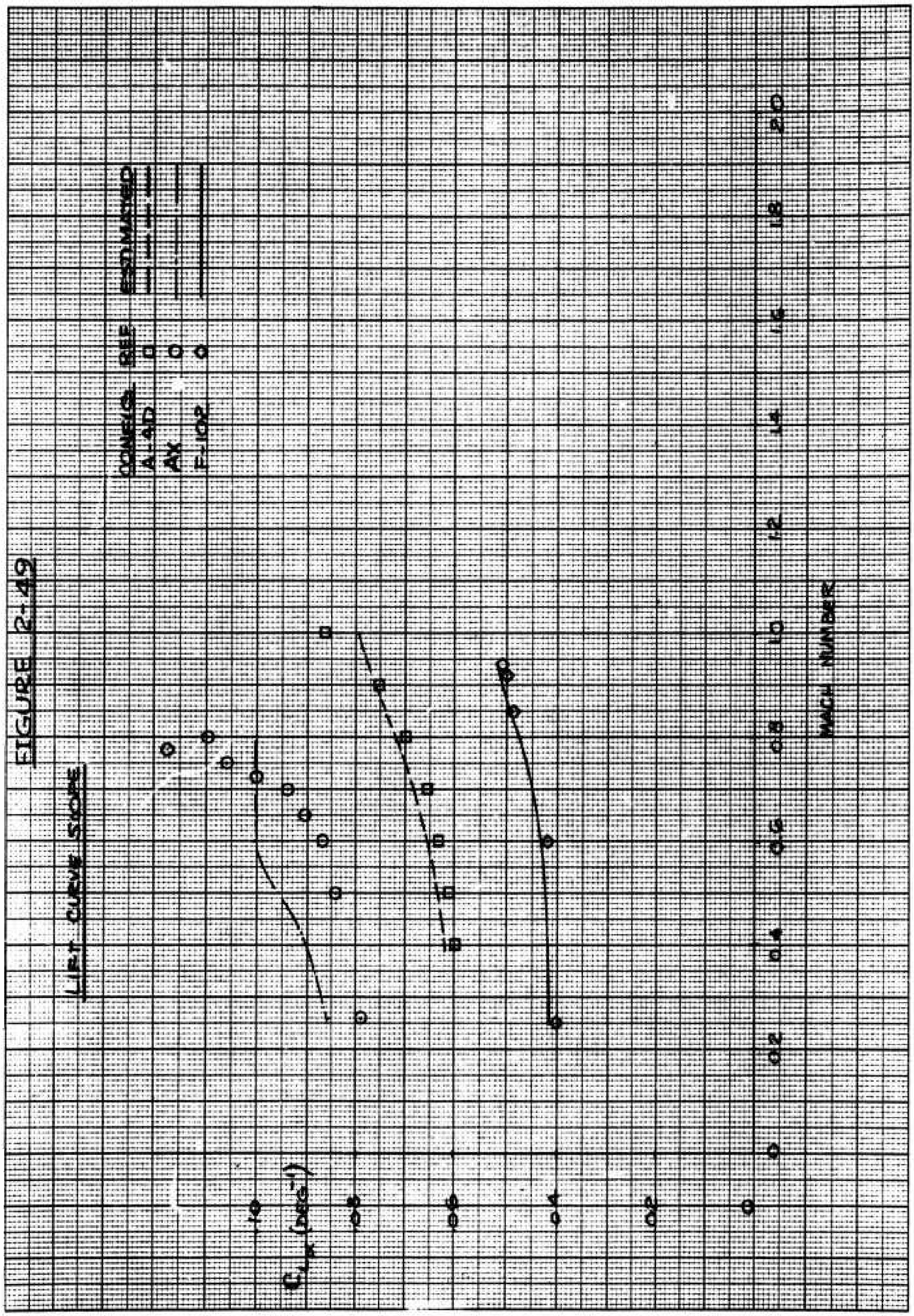
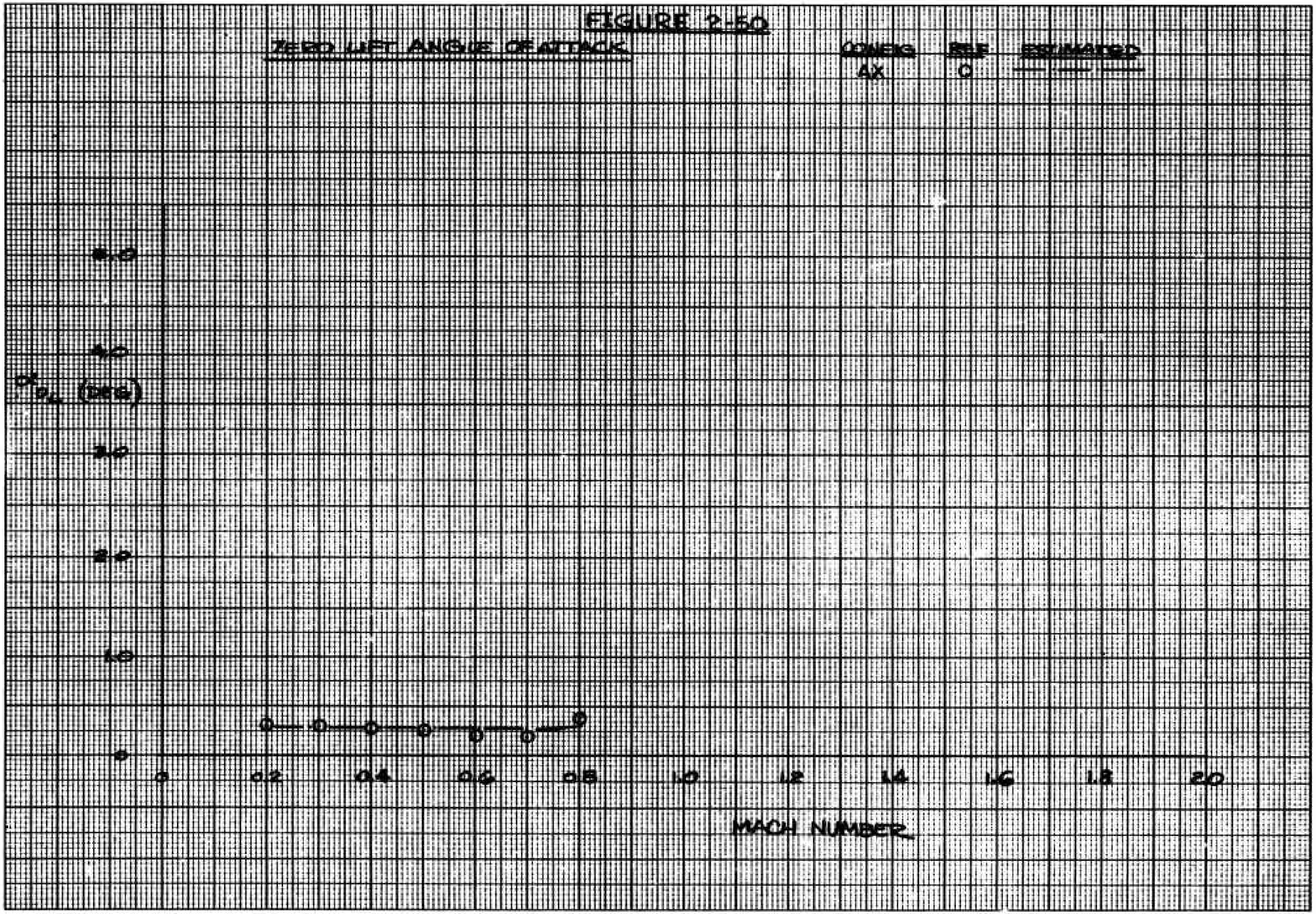


FIGURE 2-49
LIFT CURVE SLOPE
CONFIG. REF. ESTIMATED
A-4D
AX
F-102
C_{L_α} (DEG^{-1})
1.0
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER


ZERO LIFT ANGLE OF ATTACK
CONFIG
AX
SYM
O
ESTIMATED
5.0
4.0
3.0
2.0
1.0
0
α_{0L} (DEG)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER
FIGURE 2-50

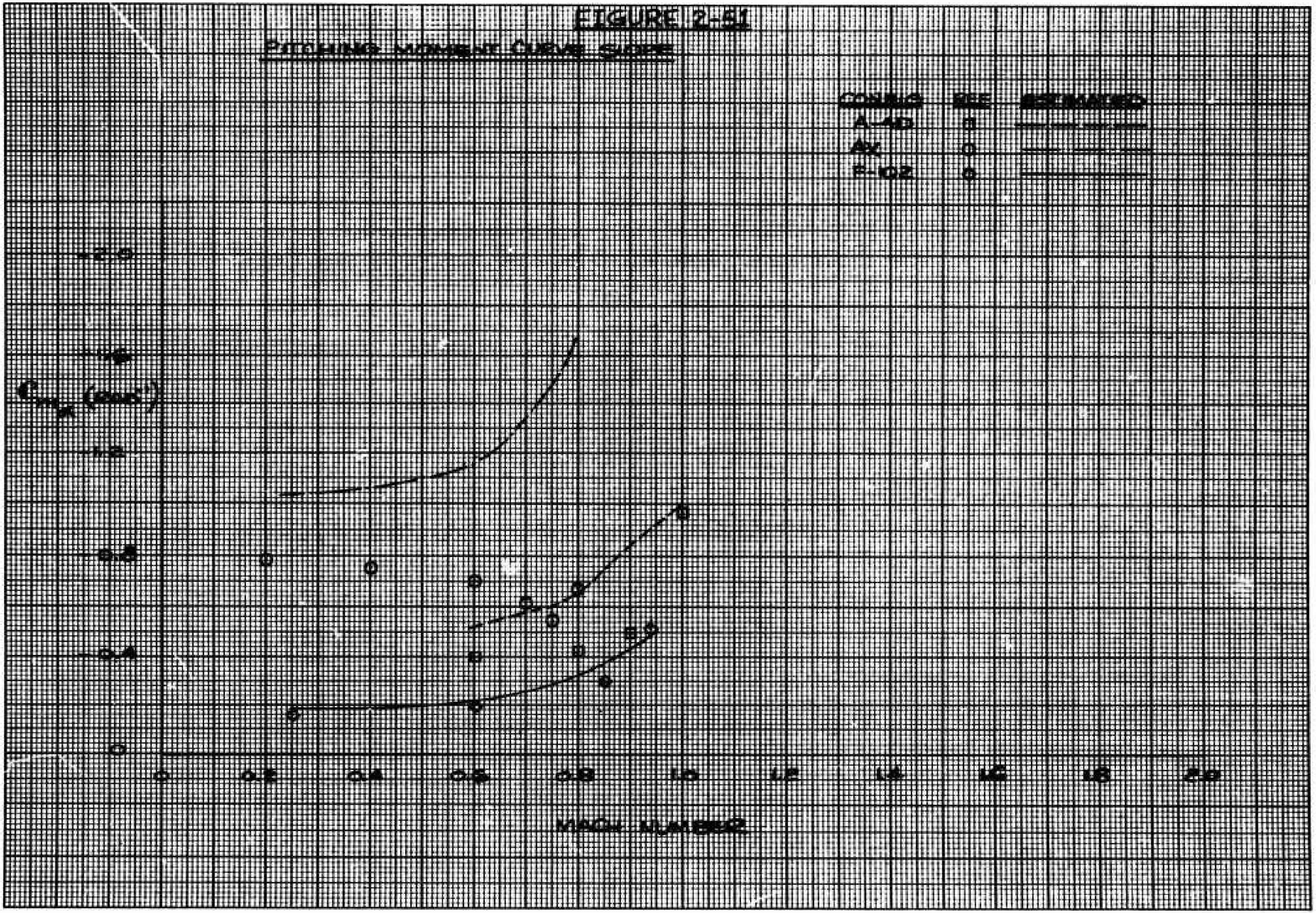


FIGURE 2-51

PITCHING MOMENT CURVE SLOPE

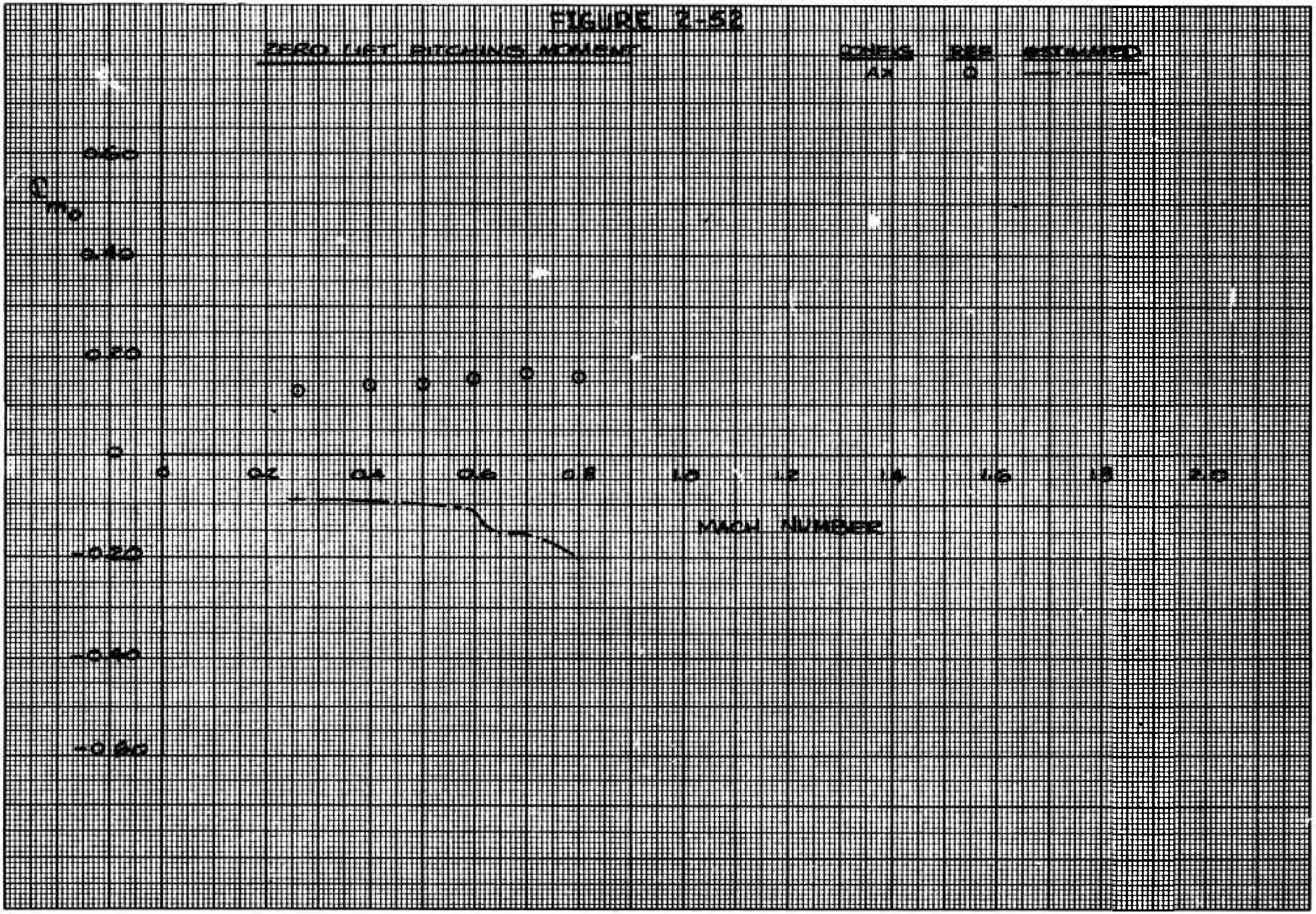


FIGURE 2-52

ZERO LIFT PITCHING MOMENT

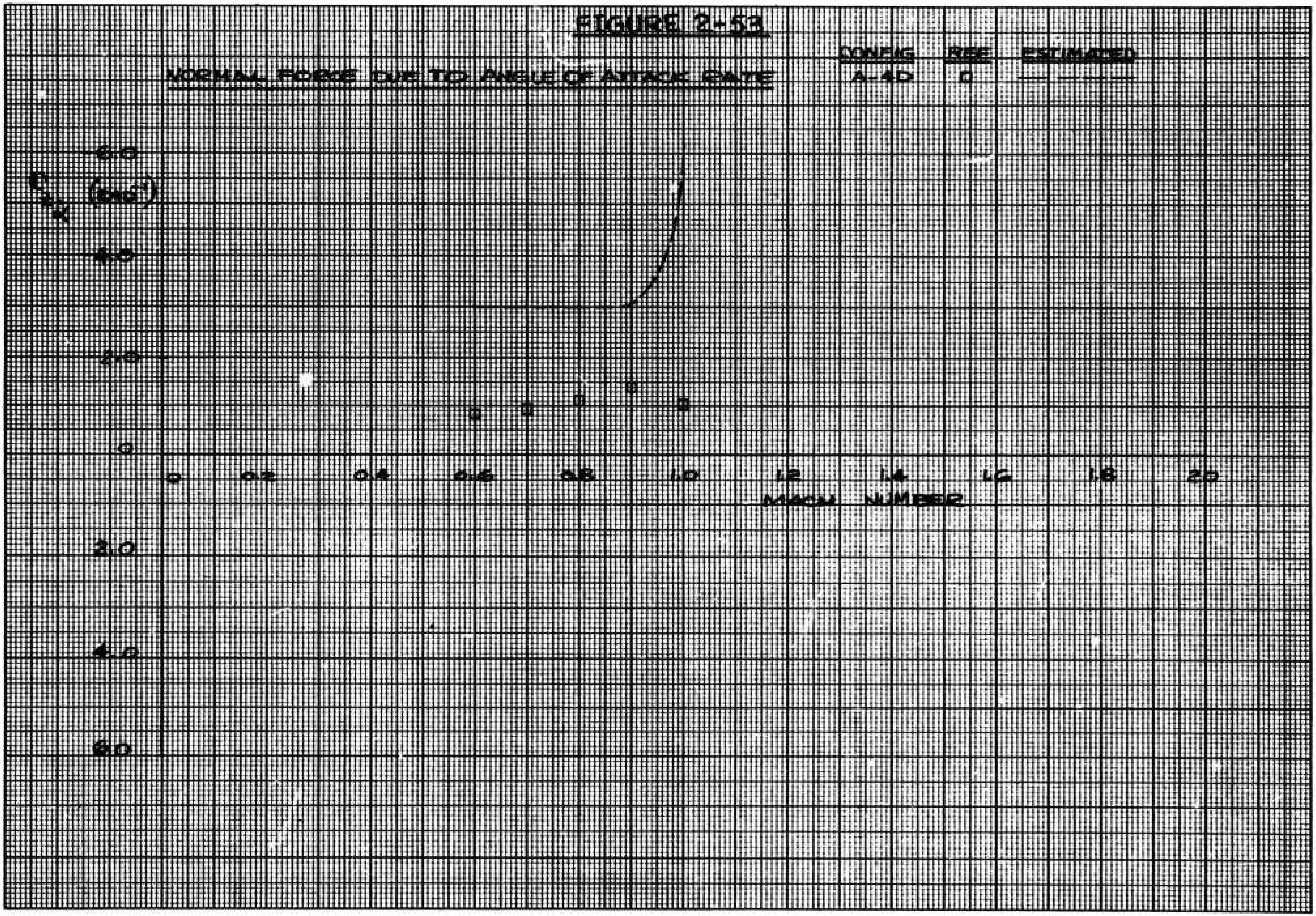


FIGURE 2-53

NORMAL FORCE DUE TO ANGLE OF ATTACK RATE

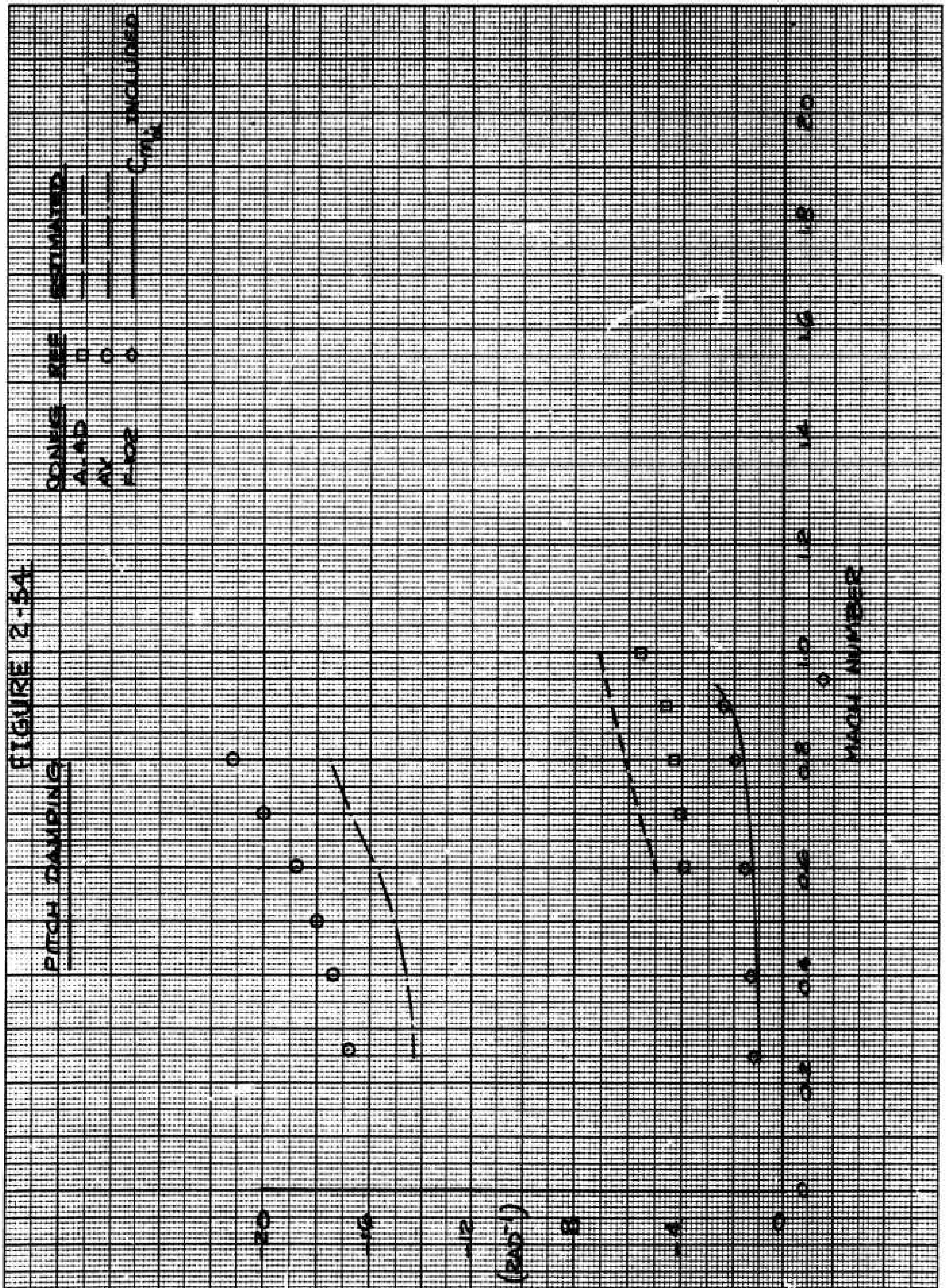


FIGURE 2-54
PITCH DAMPING
SOURCE
REF
ESTIMATED
A.A.D
AV
F-102
$C_{m_{\dot{\alpha}}}$ INCLUDED
C_{m_q} (RAD^{-1})
-20
-16
-12
-8
-4
0
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

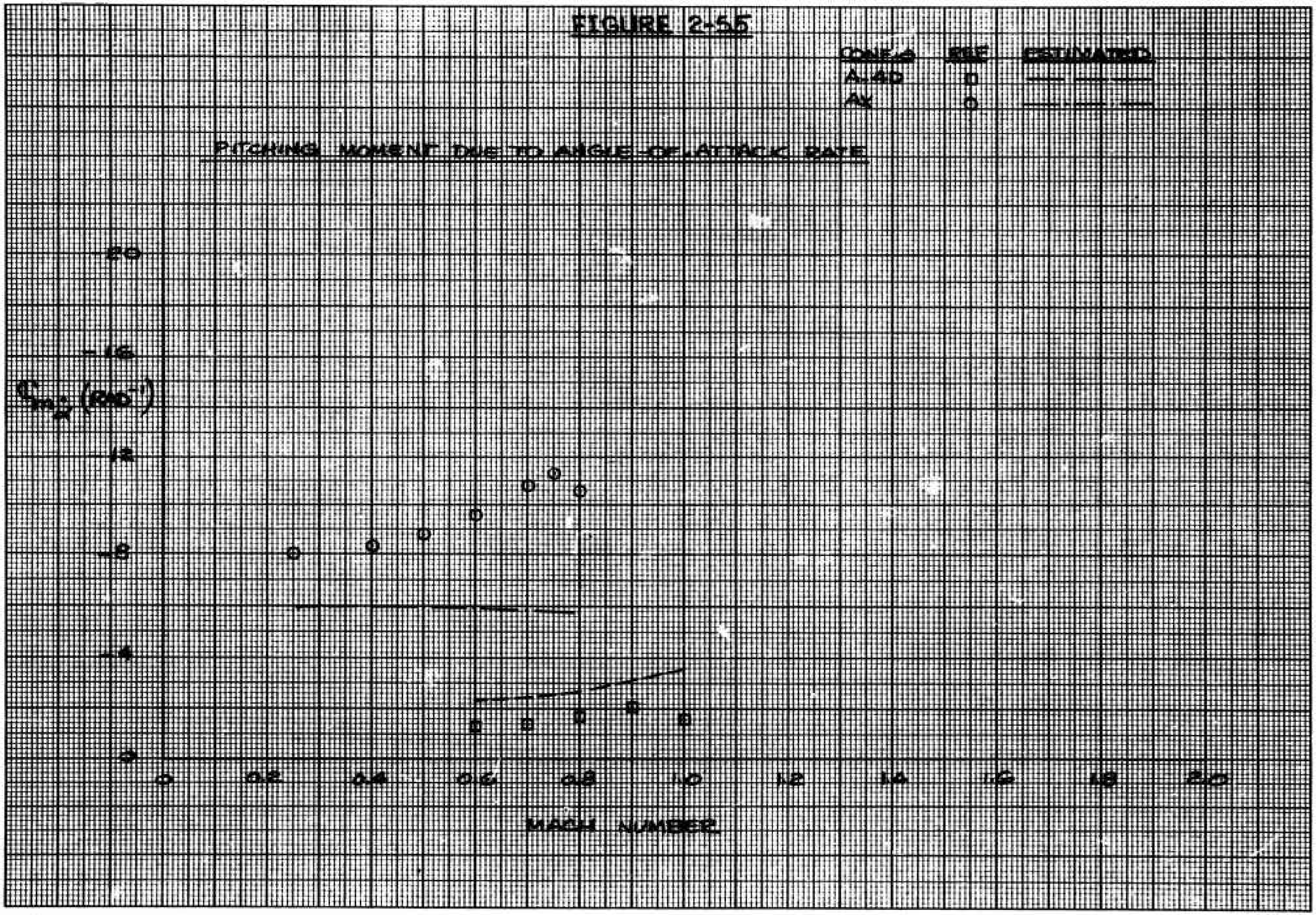


FIGURE 2-55
CONFIG
REF
ESTIMATED
A-4D
PITCHING MOMENT DUE TO ANGLE-OF-ATTACK RATE
$C_{m_{\dot{\alpha}}}$ (RAD^{-1})
20
-16
12
-8
-4
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

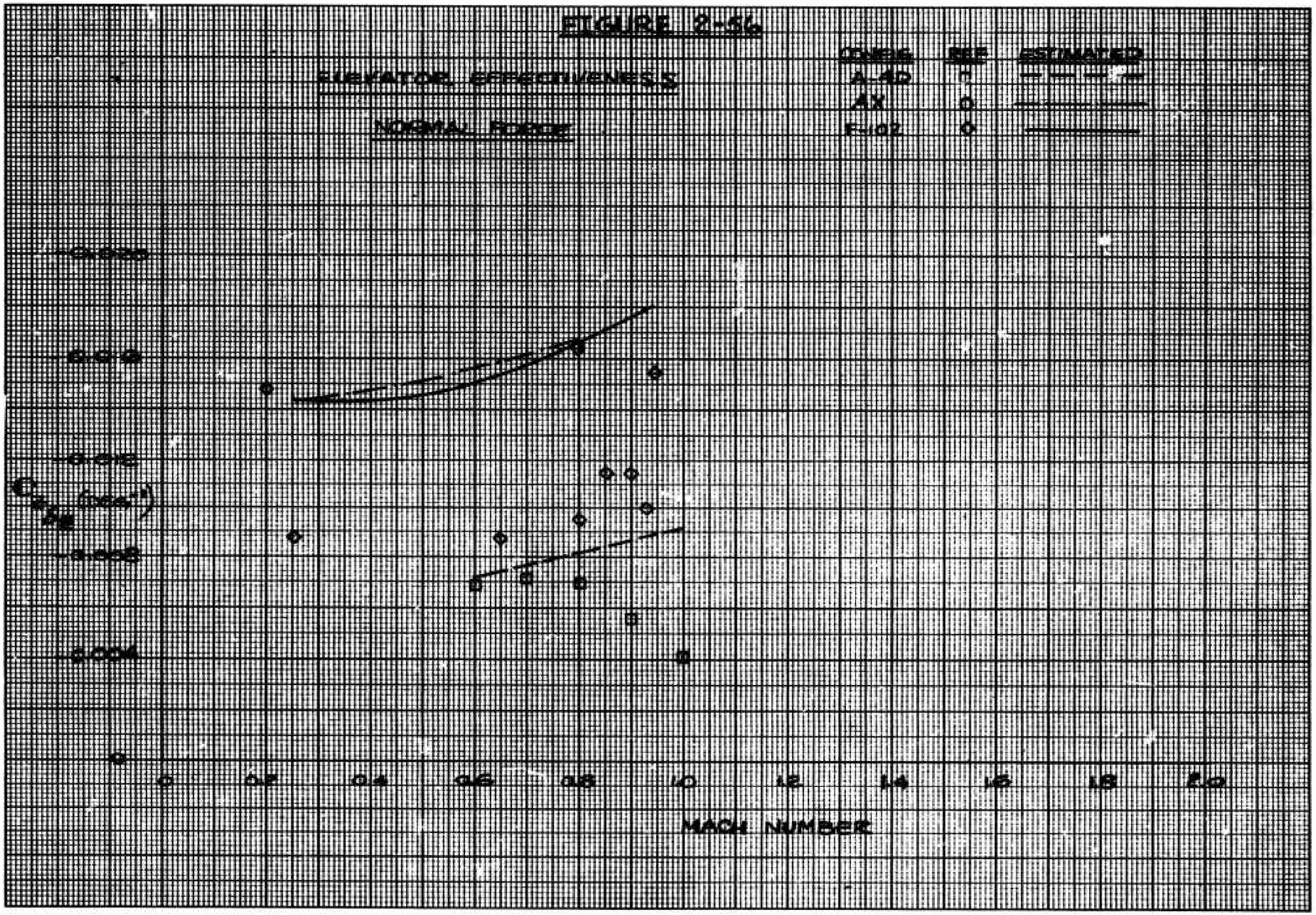


FIGURE 2-56
ELEVATOR EFFECTIVENESS
NORMAL FORCE
CONFIG. REF. ESTIMATED
A-4D
AX
F-102
-0.020
-0.016
-0.012
$C_{N_{\delta_e}}$ (deg^{-1})
-0.008
-0.004
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

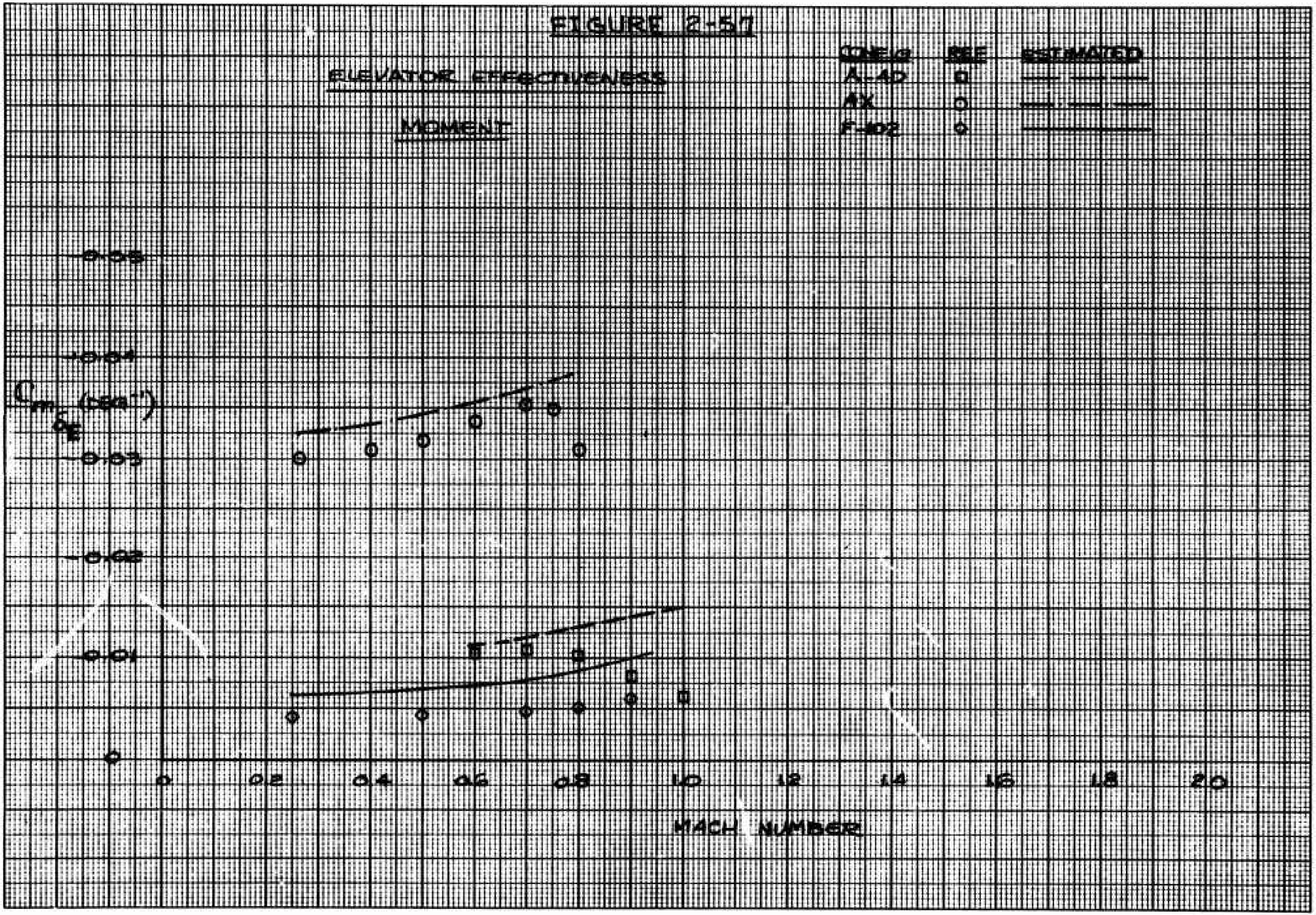


FIGURE 2-57
ELEVATOR EFFECTIVENESS
MOMENT
CONFIG
REF
ESTIMATED
A-4D
AX
F-102
$C_{m_{\delta_E}}$ (DEG^{-1})
-0.05
-0.04
-0.03
-0.02
-0.01
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

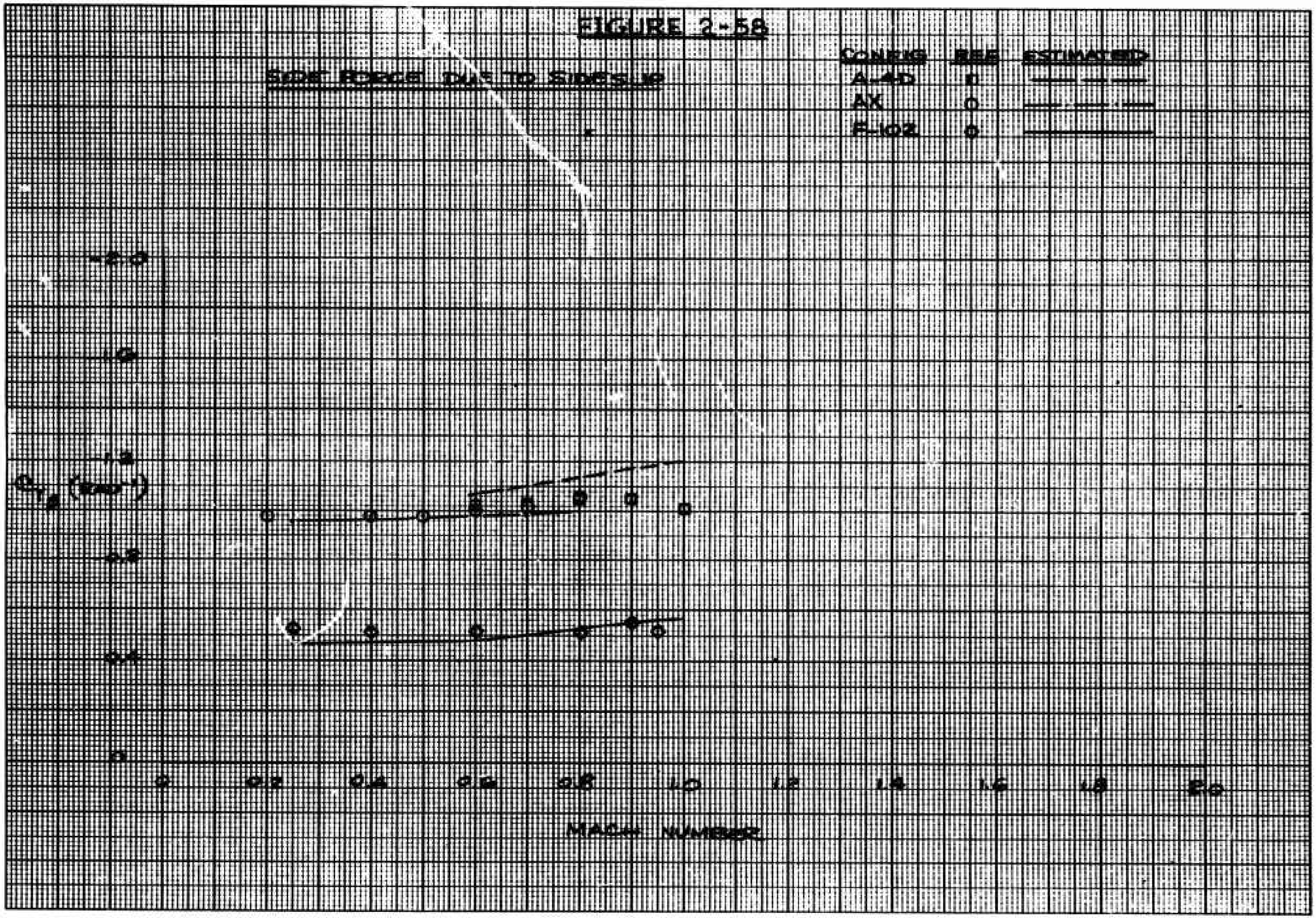
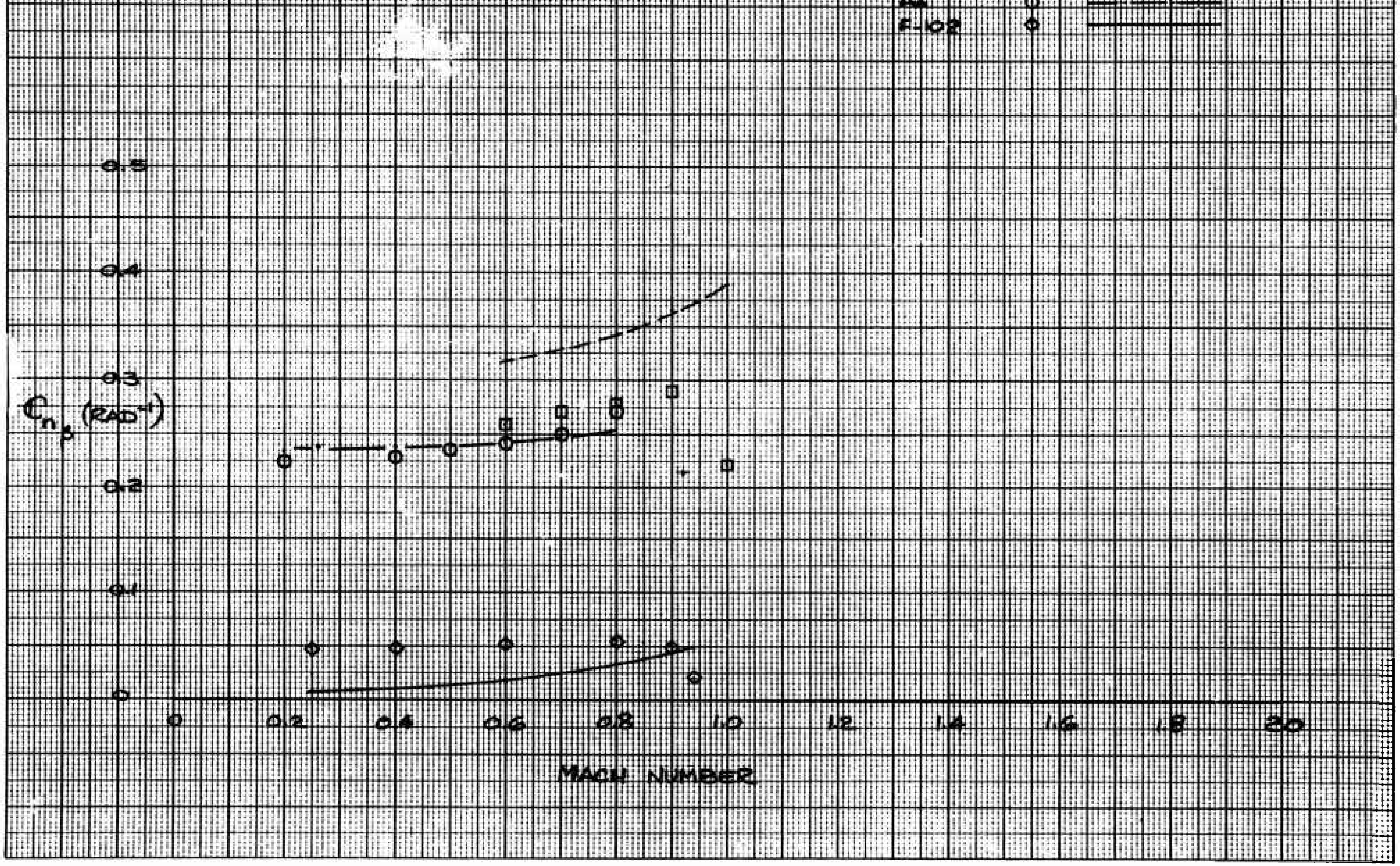


FIGURE 2-58

SIDE FORCE DUE TO SIDESLIP

FIGURE 2-59

YAWING MOMENT DUE TO SIDESLIP



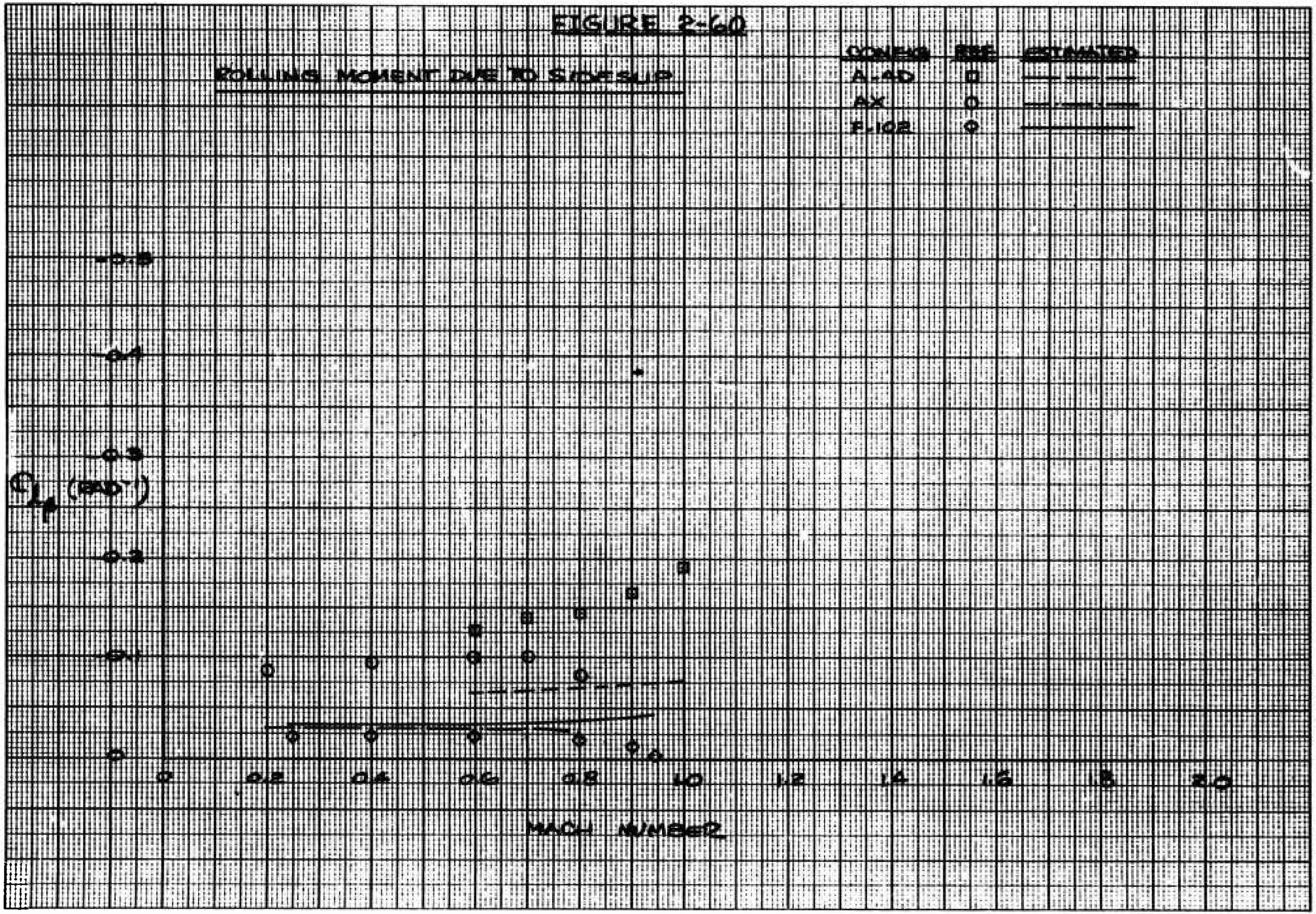


FIGURE 2-60
ROLLING MOMENT DUE TO SIDESLIP
A-4D
AX
F-102
ESTIMATED
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

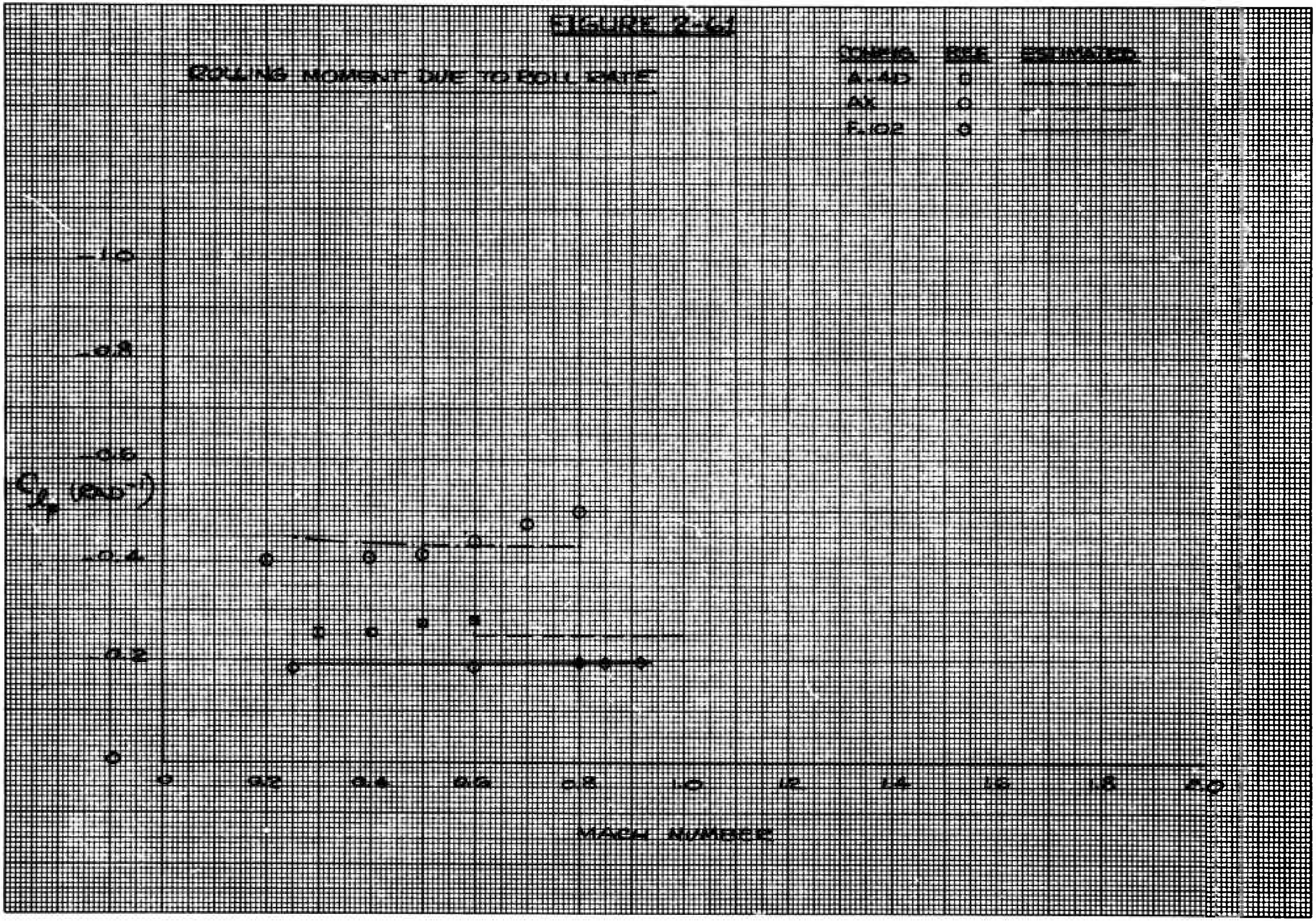


FIGURE 2-6J
ROLLING MOMENT DUE TO ROLL RATE
CONFIG.
REF.
ESTIMATED
A-4D
AX
F-102
-1.0
-0.8
-0.6
C_{l_p} (RAD^{-1})
-0.4
-0.2
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

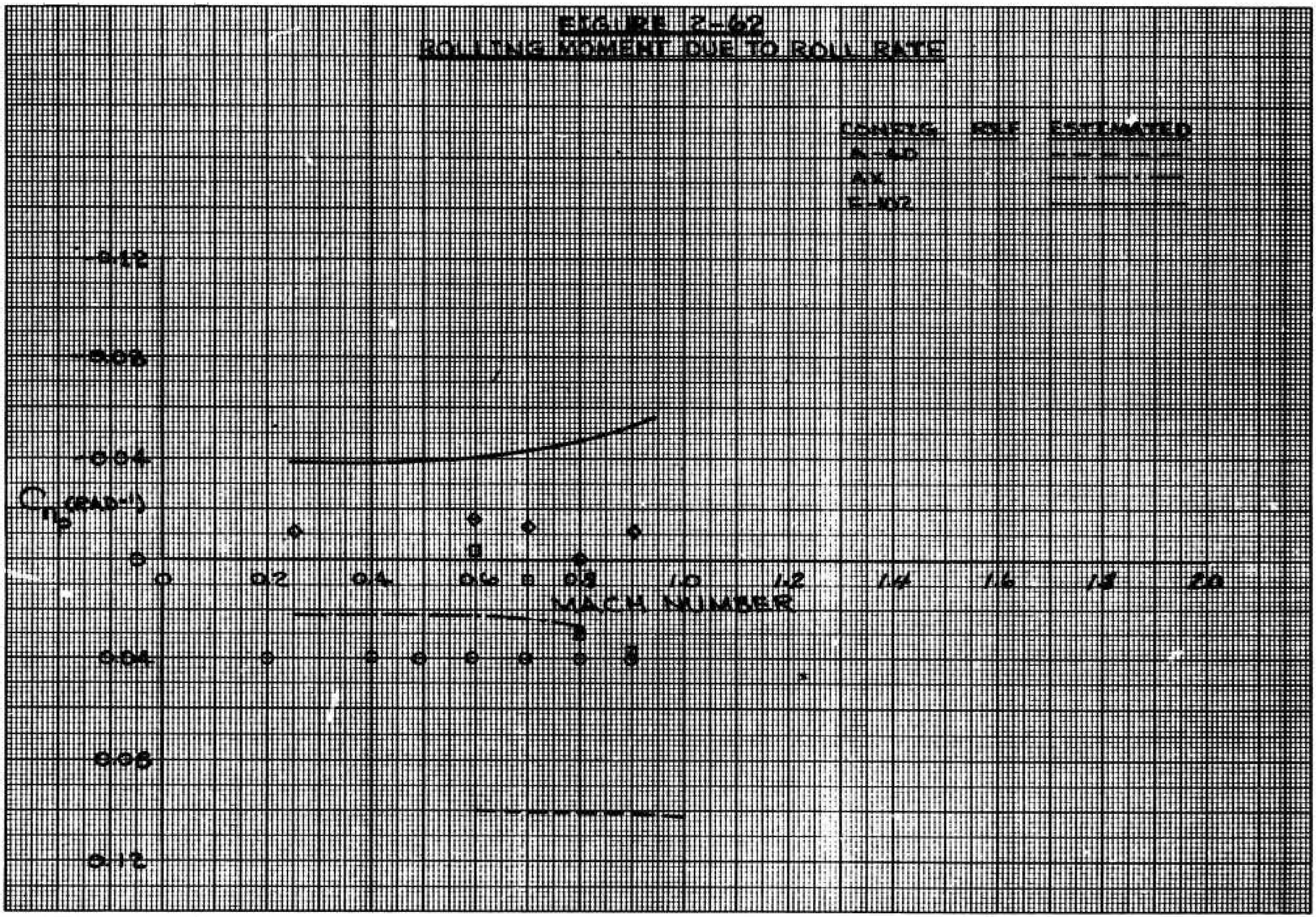


FIGURE 2-62
ROLLING MOMENT DUE TO ROLL RATE

FIGURE 2-63

ROLLING MOMENT DUE TO YAW RATE

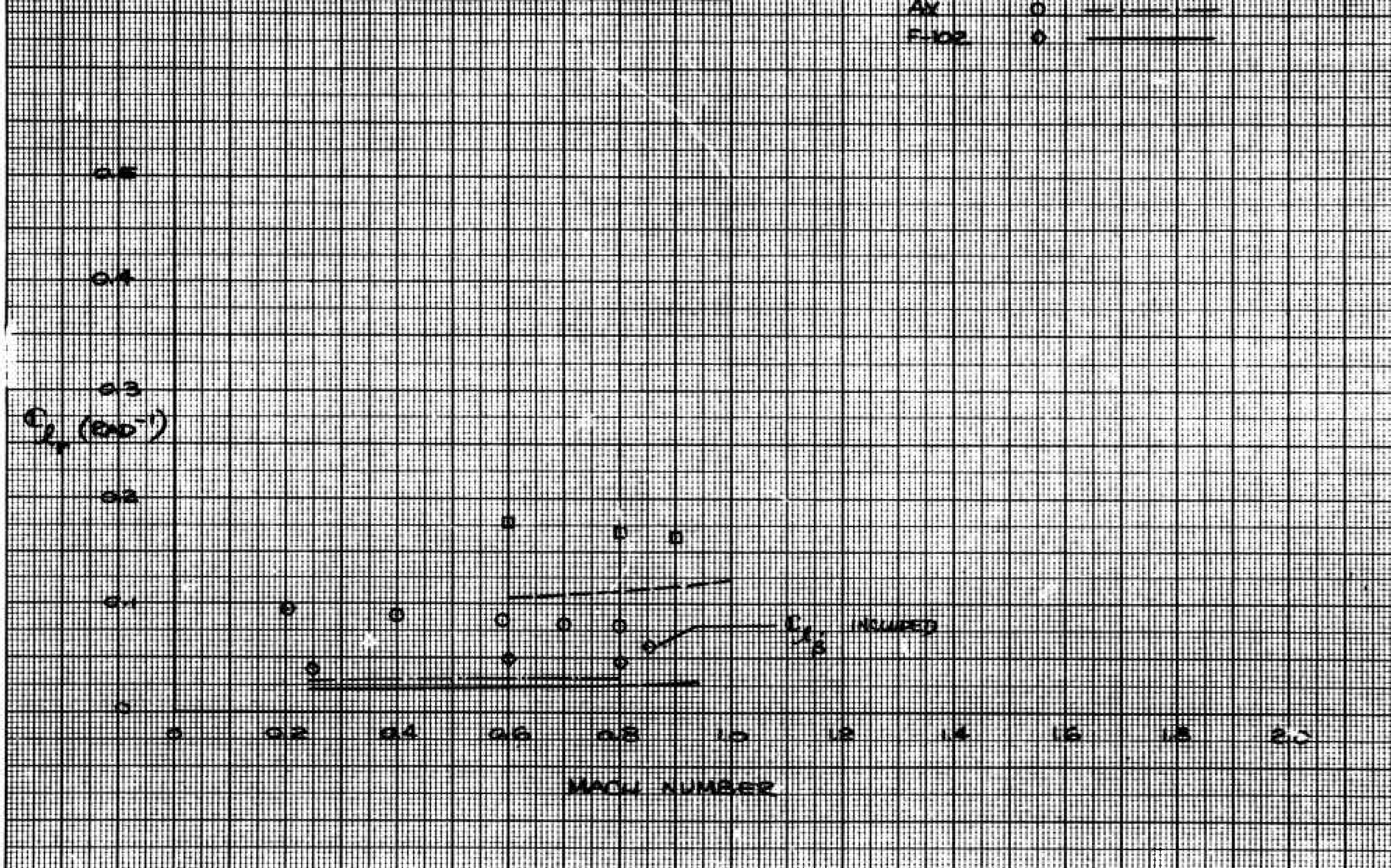
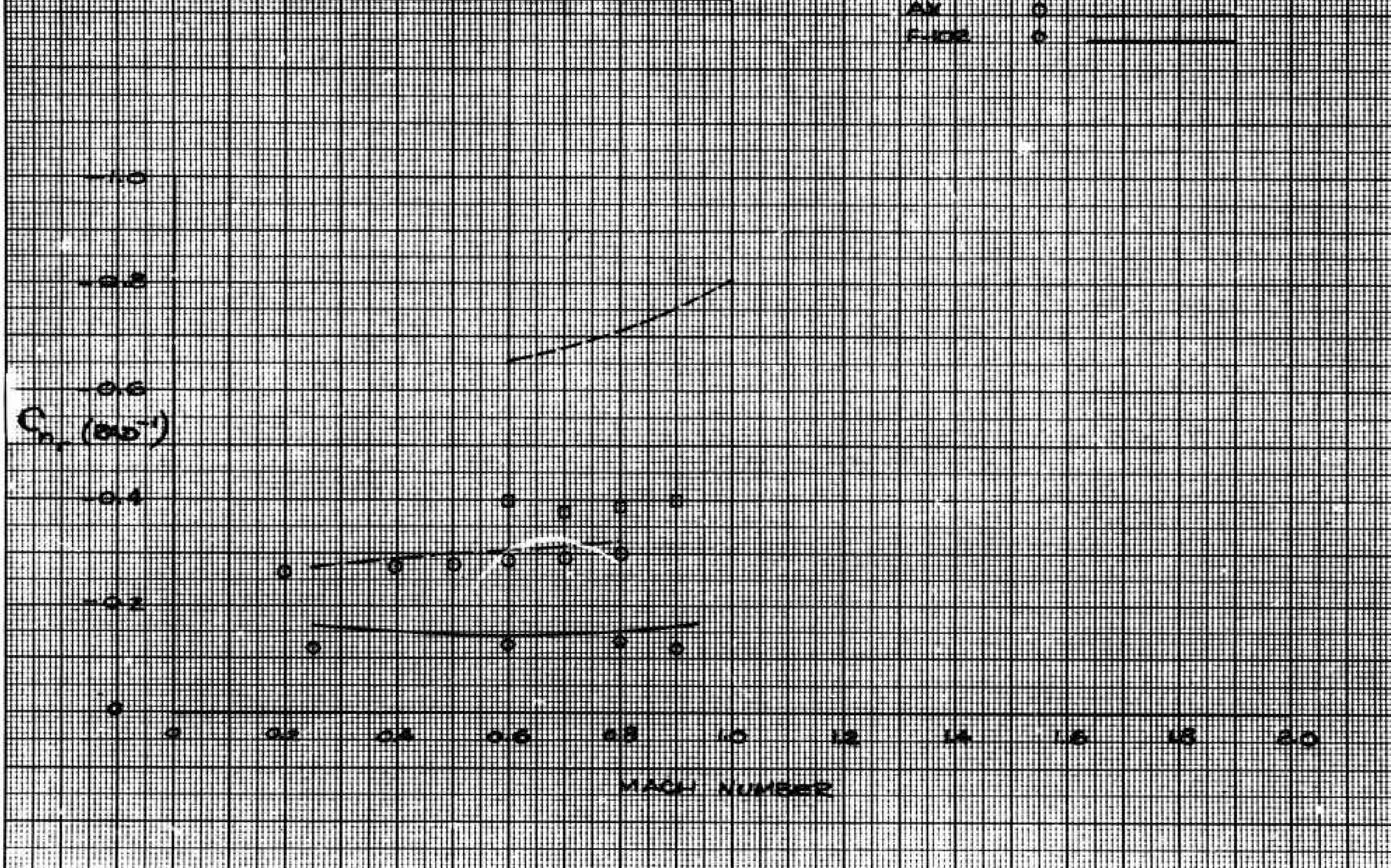


FIGURE 2-64

YAWING MOMENT DUE TO YAW RATE



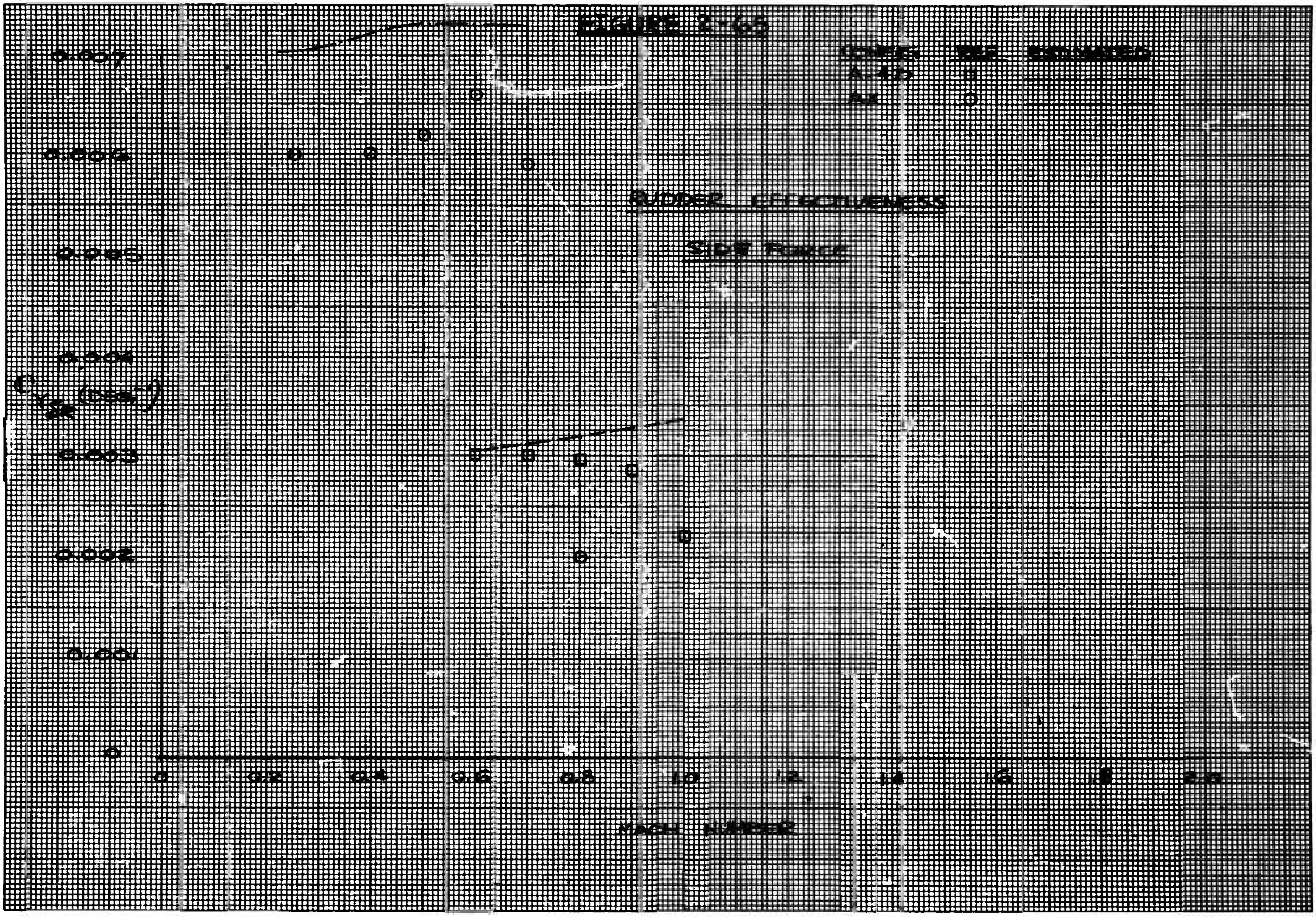


FIGURE 2-65
RUDDER EFFECTIVENESS
SIDE FORCE
ESTIMATED
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

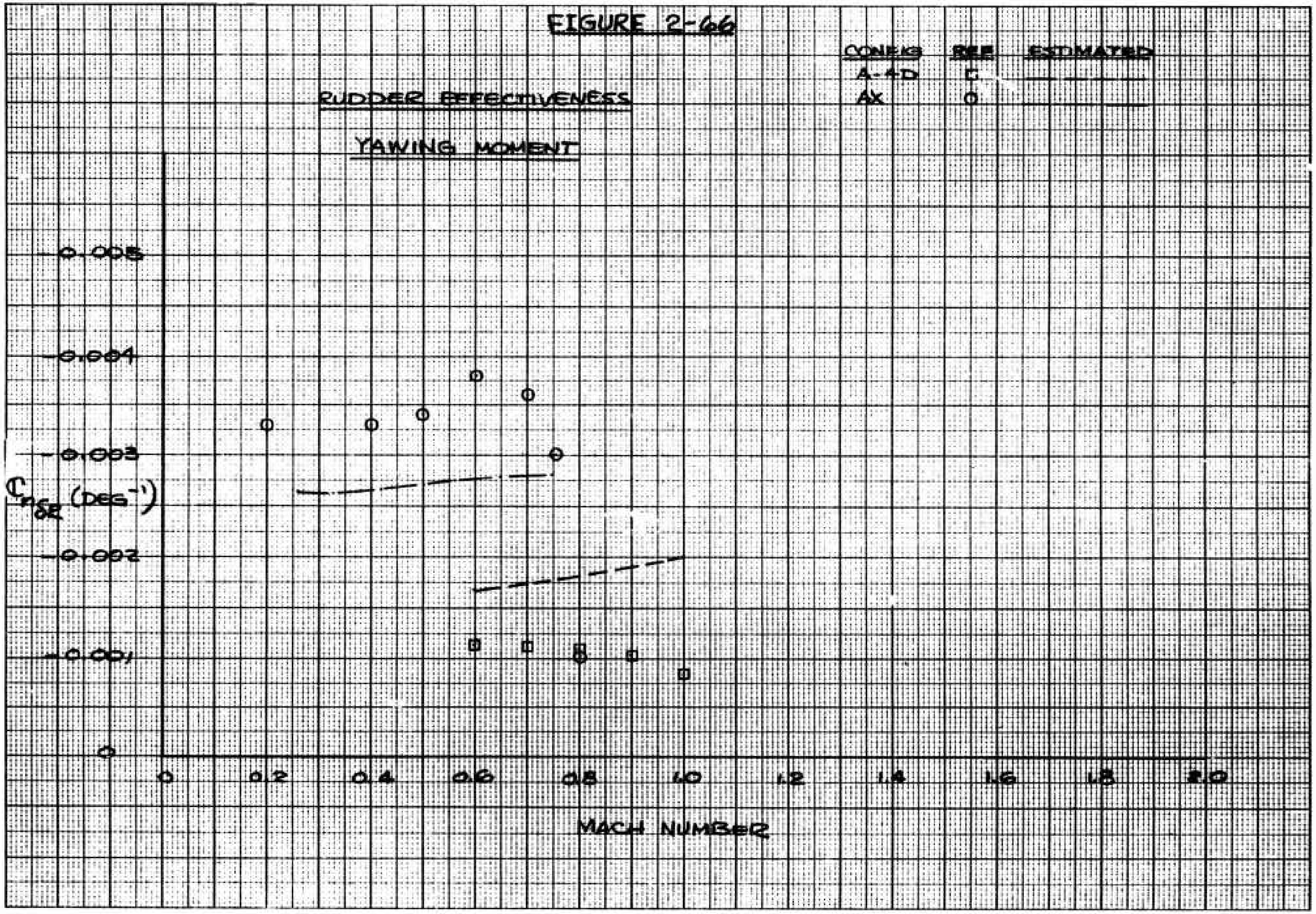


FIGURE 2-66
RUDDER EFFECTIVENESS
YAWING MOMENT
CONFIG REF ESTIMATED
A-4D
AX
-0.005
-0.004
-0.003
-0.002
-0.001
0
$C_{n_{\delta R}}$ (DEG^{-1})
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
MACH NUMBER

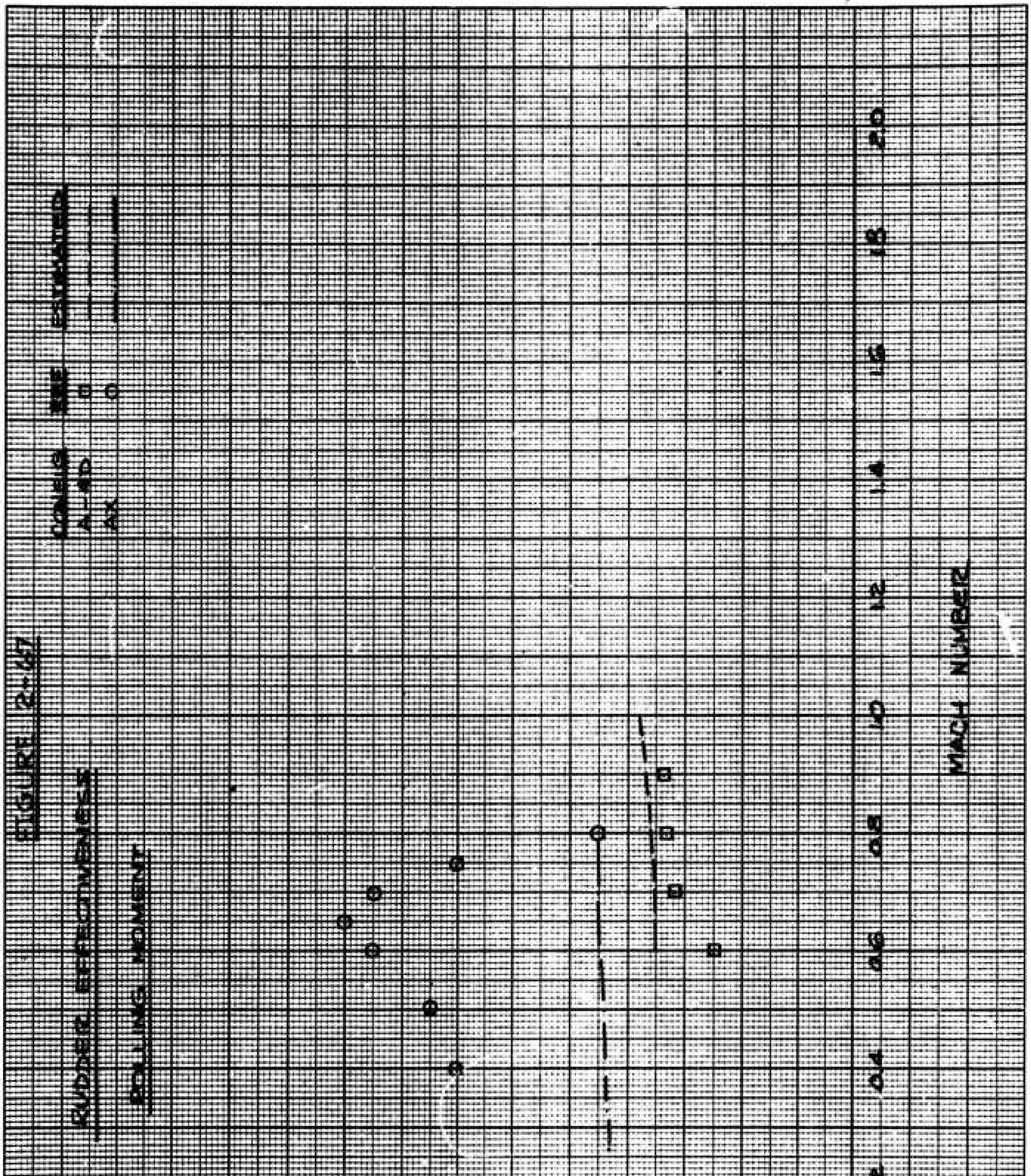


FIGURE 2-67
RUDDER EFFECTIVENESS
ROLLING MOMENT
CONFIG
A-4D
AX
SYM
ESTIMATED
$C_{l_{\delta R}}$ (DEG^{-1})
0.0010
0.0008
0.0006
0.0004
0.0002
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

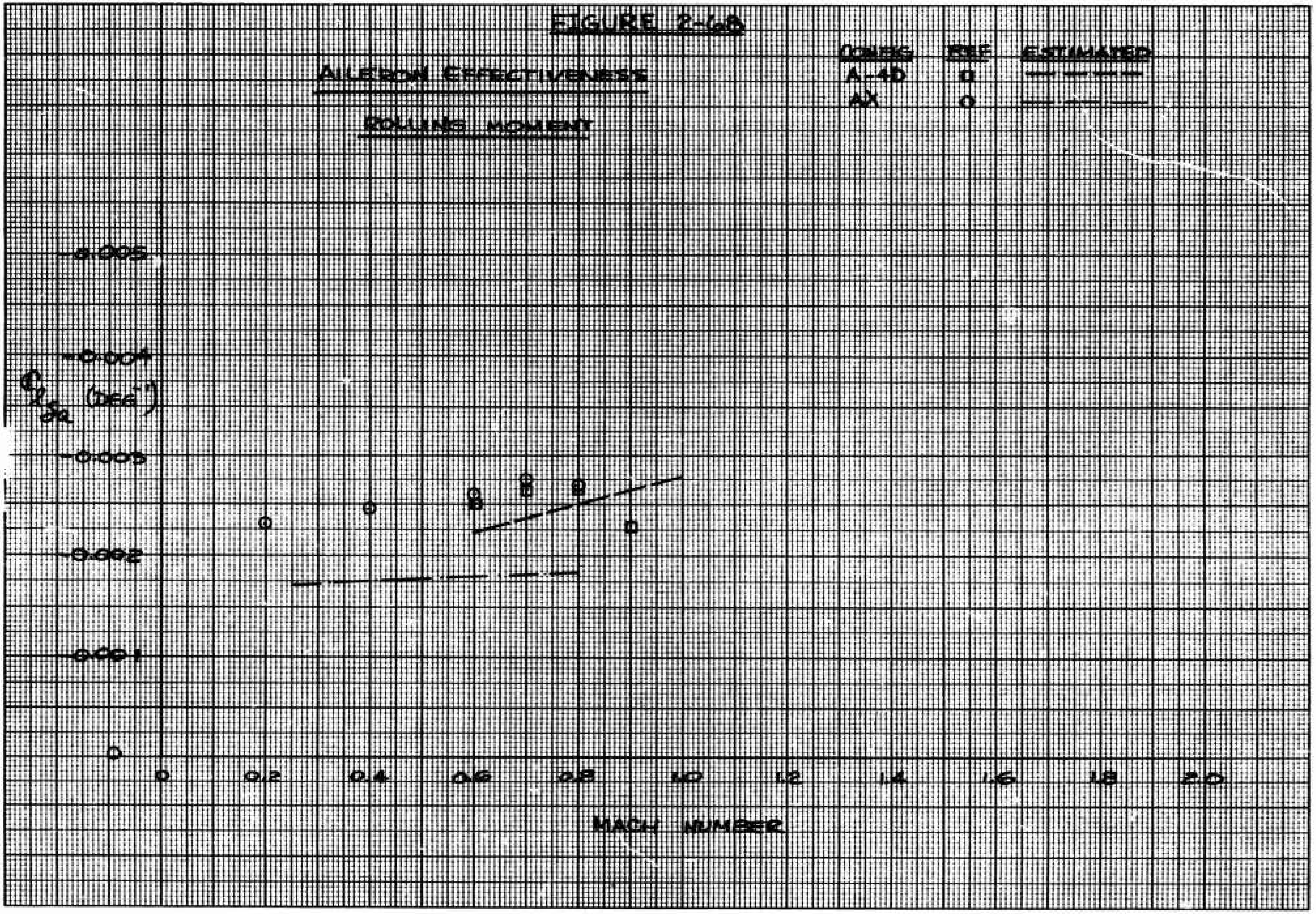

AILERON EFFECTIVENESS
ROLLING MOMENT
CONFIG. REF. ESTIMATED
A-4D □
AX ○
-0.005
-0.004
-0.003
-0.002
-0.001
0
$C_{l_{\delta a}}$ (DEG⁻¹)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

FIGURE 2-68

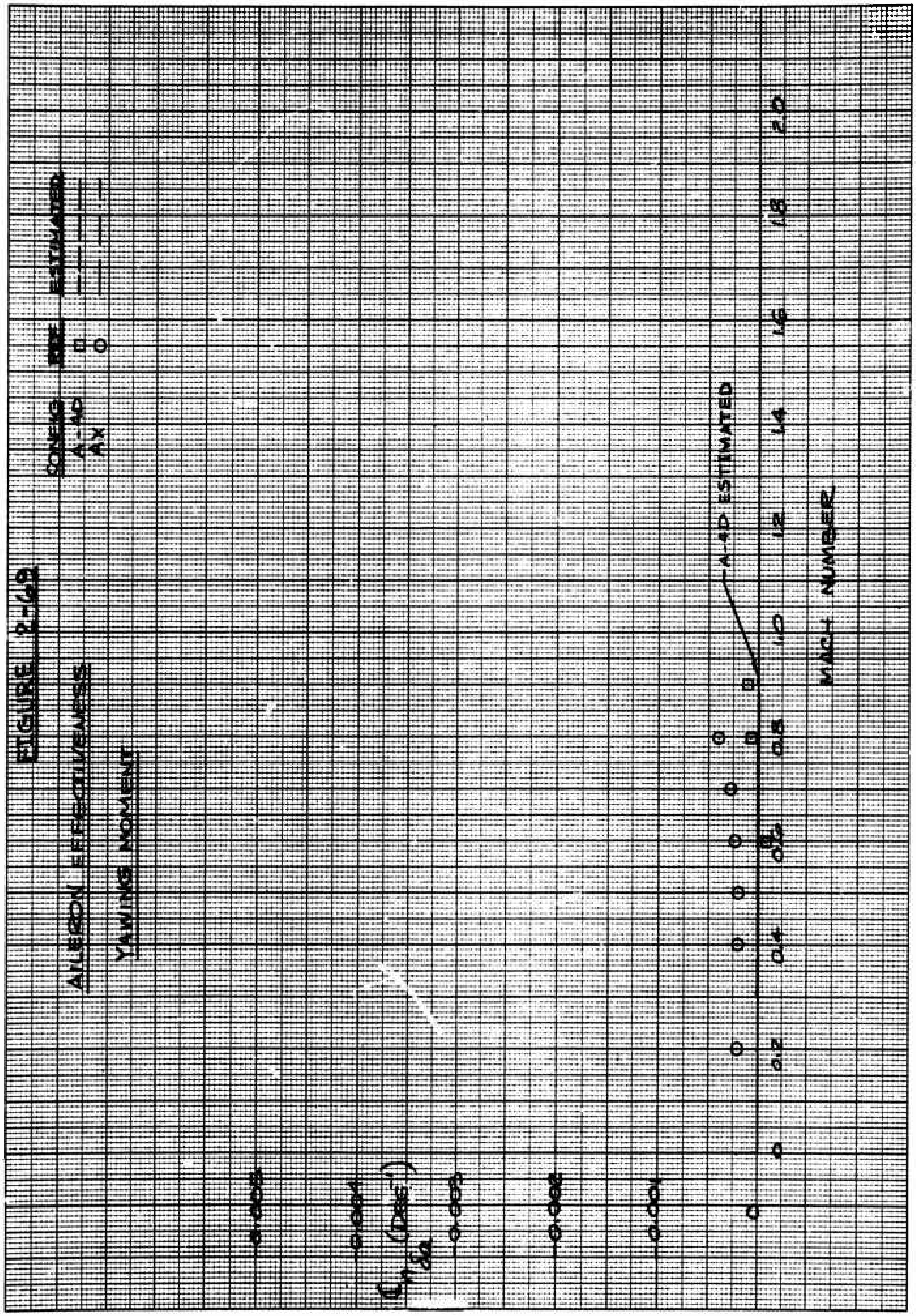


FIGURE 2-68
AILERON EFFECTIVENESS
YAWING MOMENT
CONFIG
A-4D
A-X
ESTIMATED
A-4D ESTIMATED
MACH NUMBER
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
-0.005
-0.004
-0.003
-0.002
-0.001
0
(DEG⁻¹)

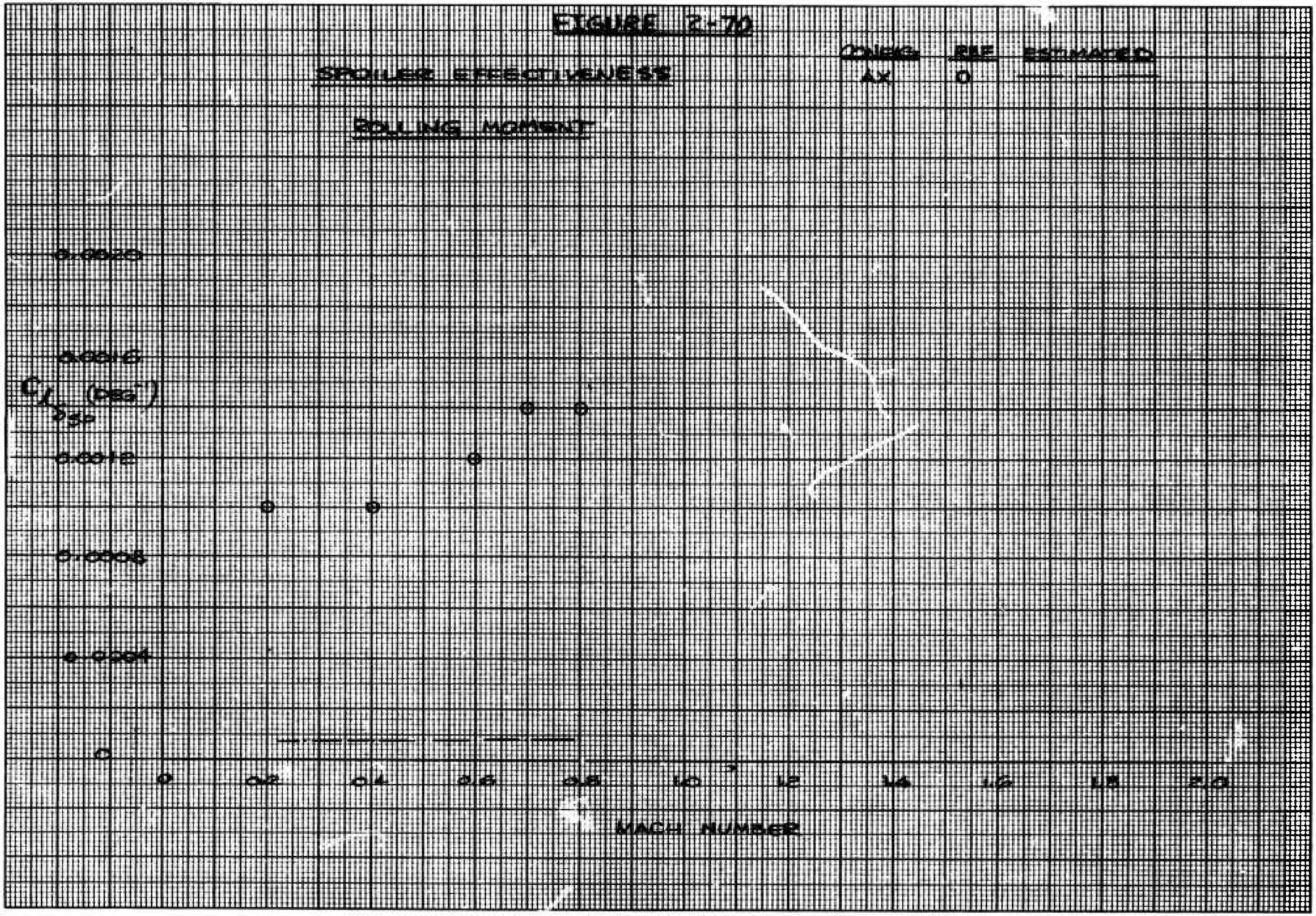

SPOILER EFFECTIVENESS
ROLLING MOMENT
CONFIG. REF. ESTIMATED
AX 0
$C_{l_{\delta_{SP}}}$ (DEG^{-1})
0.0020
0.0016
0.0012
0.0008
0.0004
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

FIGURE 2-70

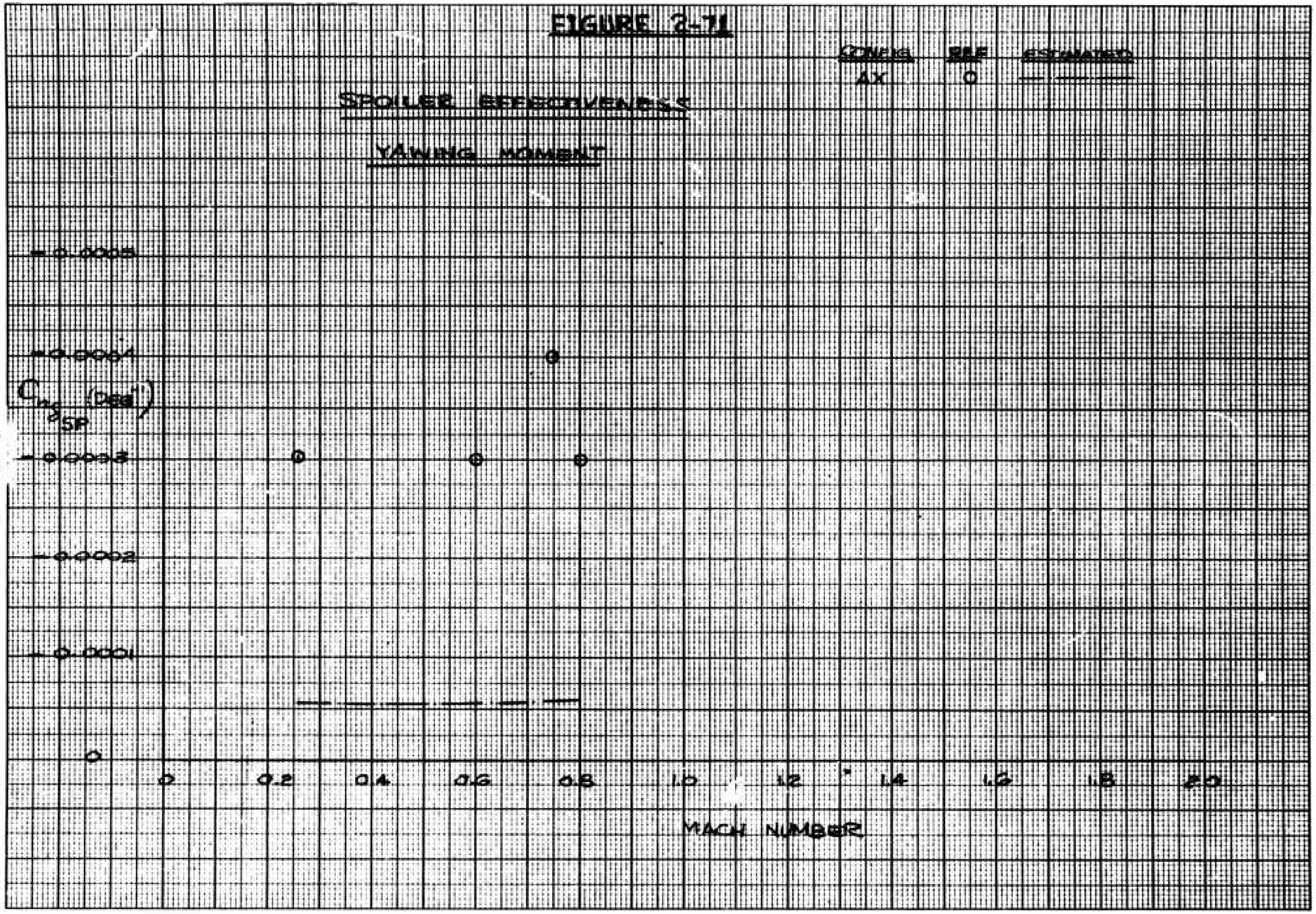
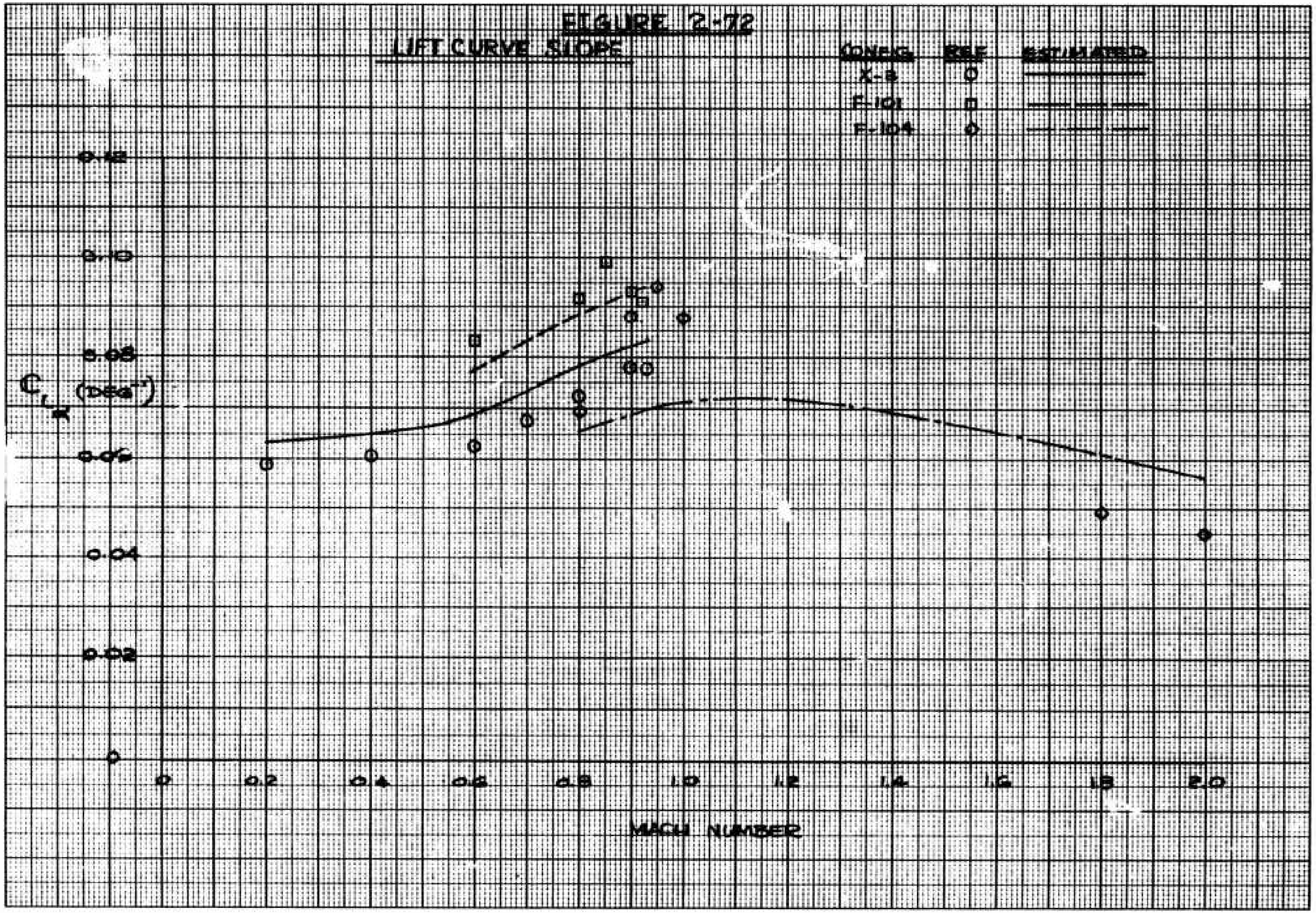


FIGURE 2-71
CONFIG
REF
ESTIMATED
AX
SPOILER EFFECTIVENESS
YAWING MOMENT
-0.0005
-0.0004
$C_{n_{\delta_{SP}}}$ (DEG^{-1})
-0.0003
-0.0002
-0.0001
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

FIGURE 2-72
LIFT CURVE SLOPE



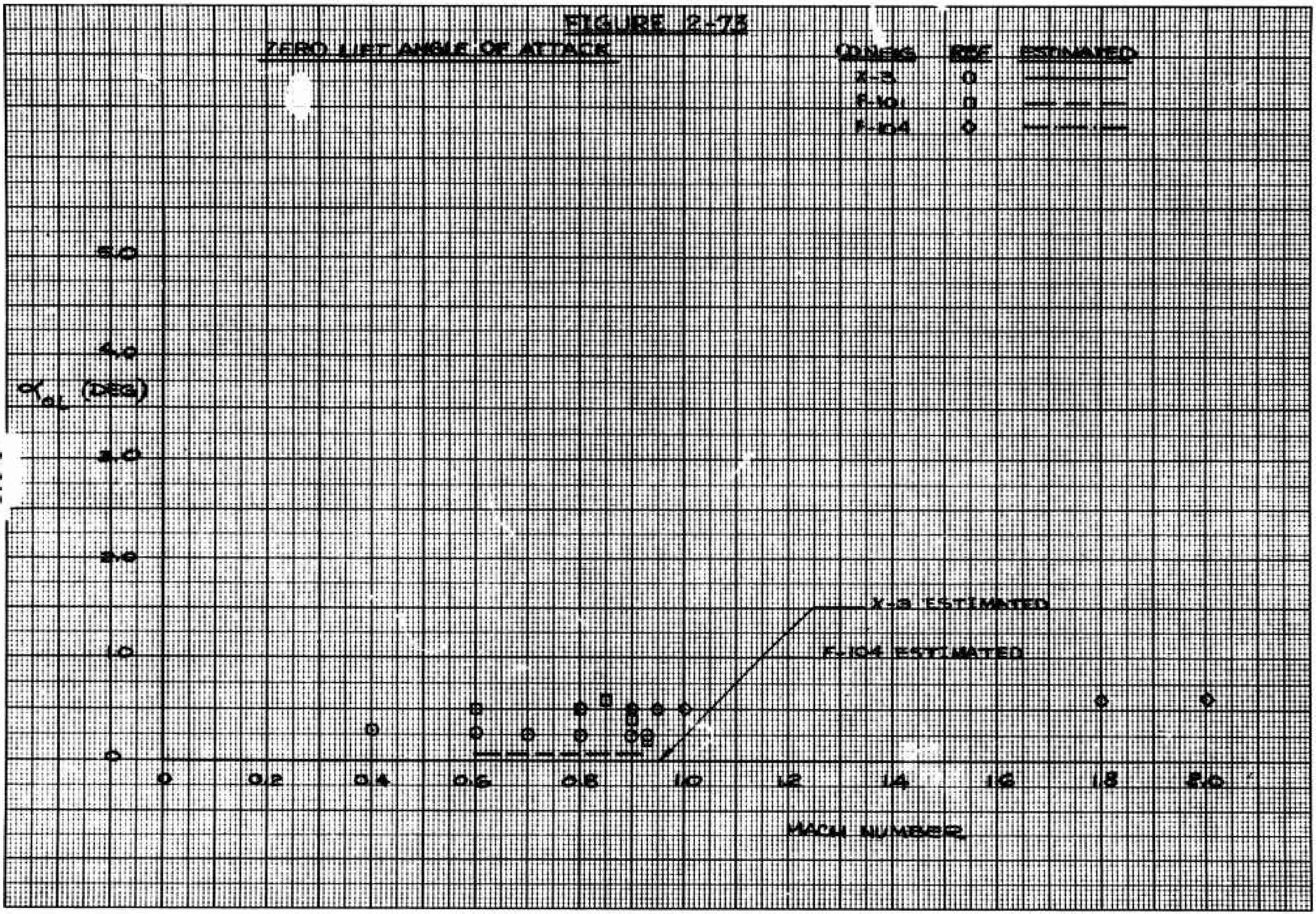


FIGURE 2-73

ZERO LIFT ANGLE OF ATTACK

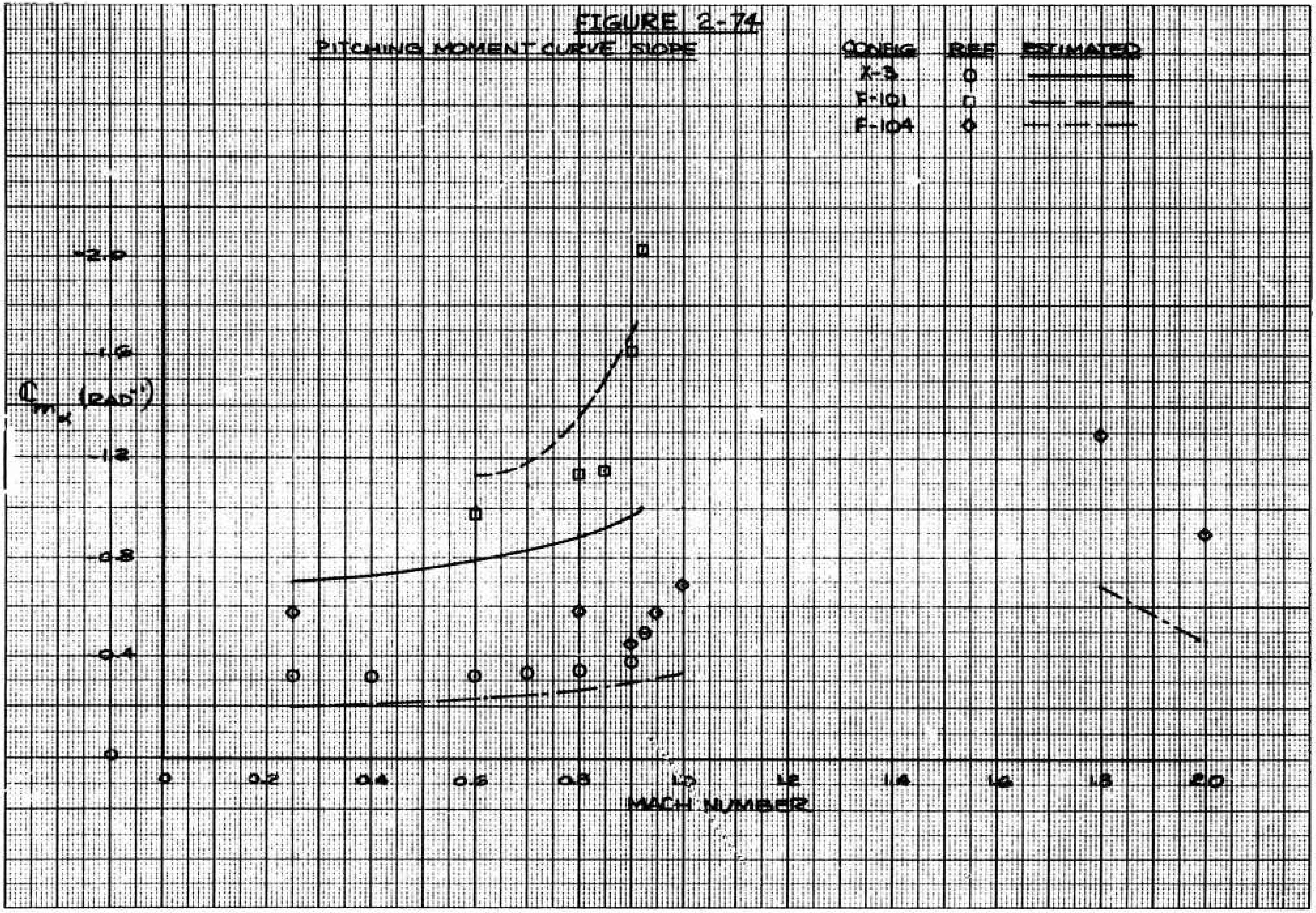


FIGURE 2-74
PITCHING MOMENT CURVE SLOPE

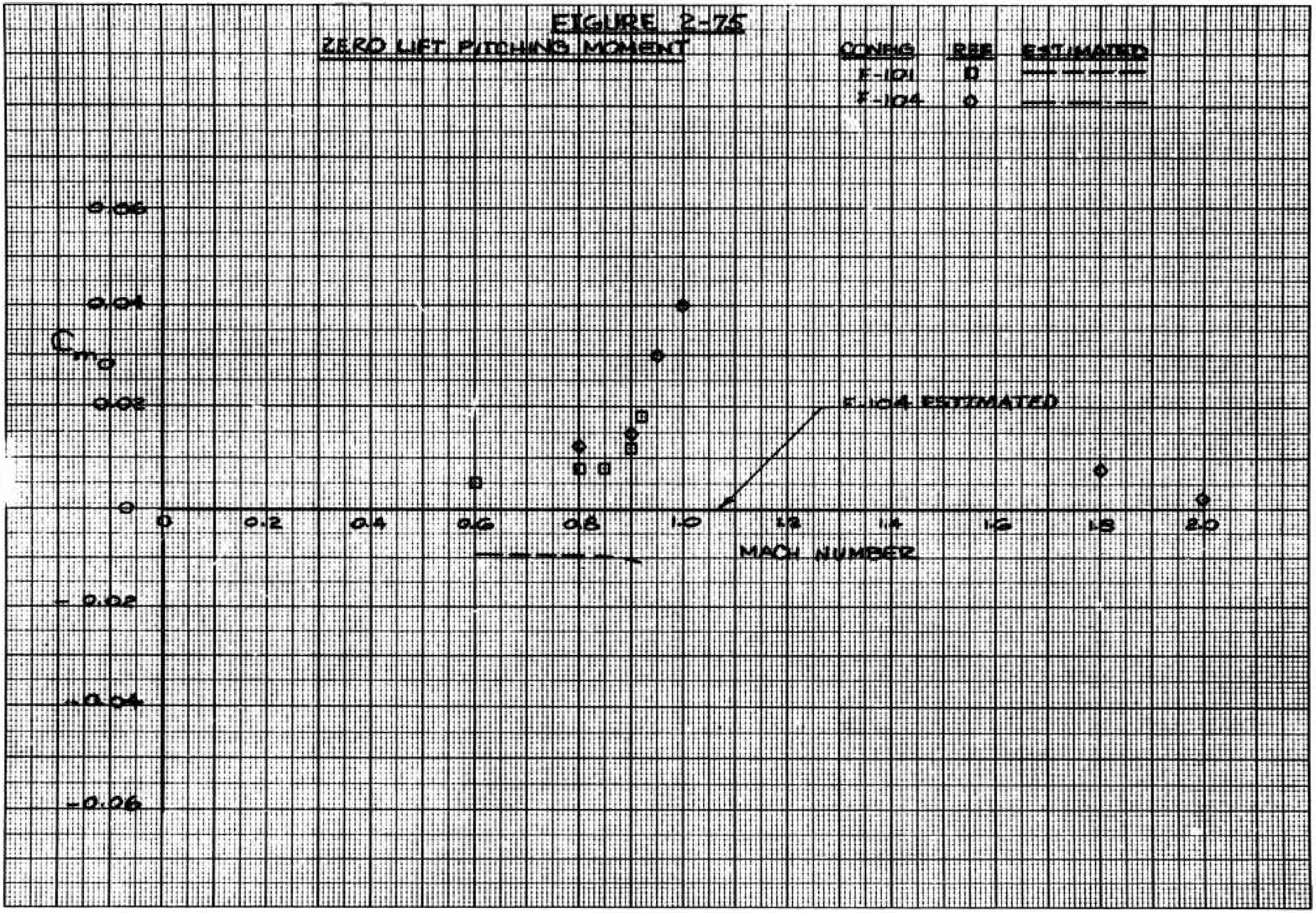


FIGURE 2-75
ZERO LIFT PITCHING MOMENT
CONFIG
F-101
F-104
RSE
ESTIMATED
F-104 ESTIMATED
C_{m_0}
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

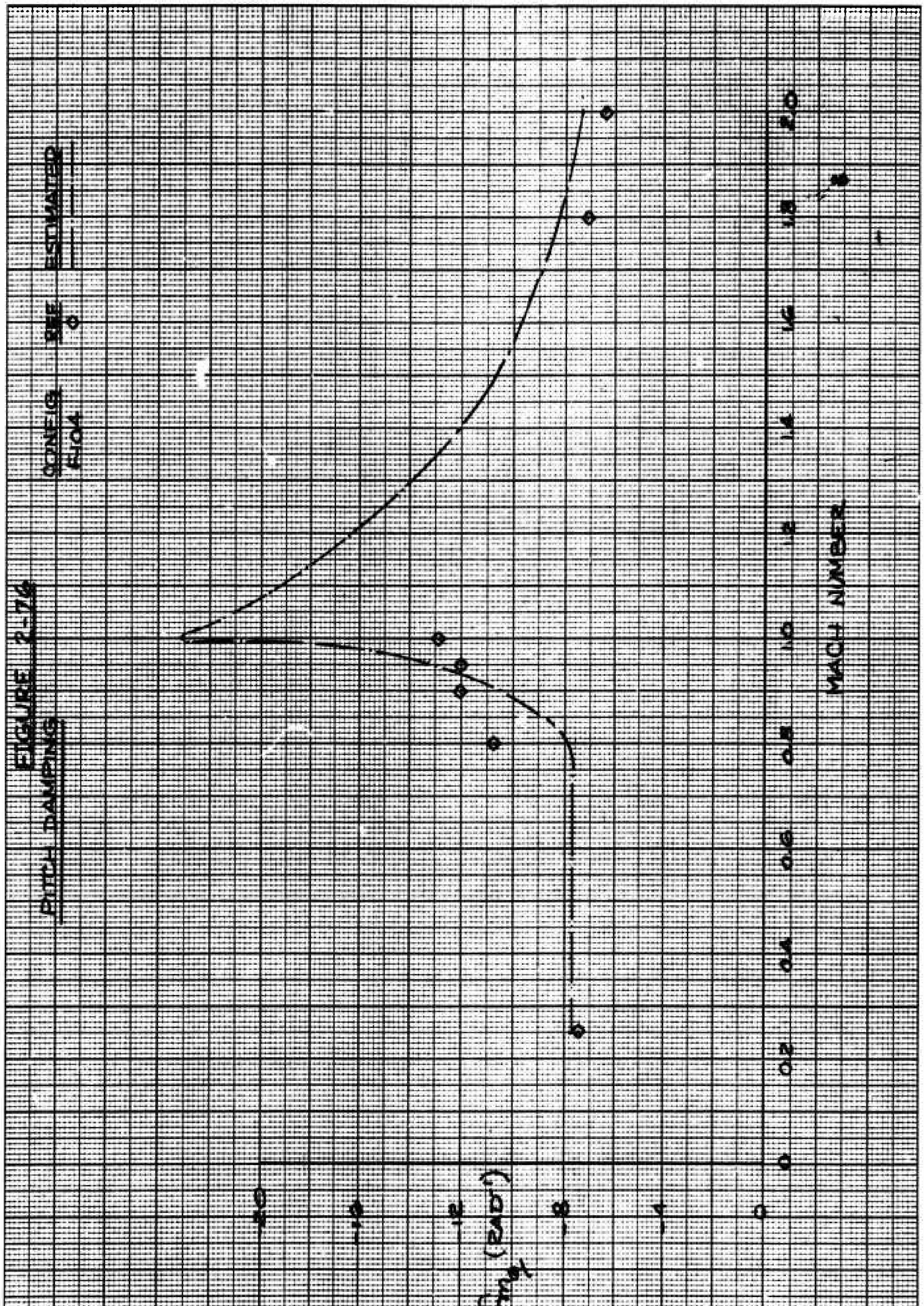


FIGURE 2-76
PITCH DAMPING

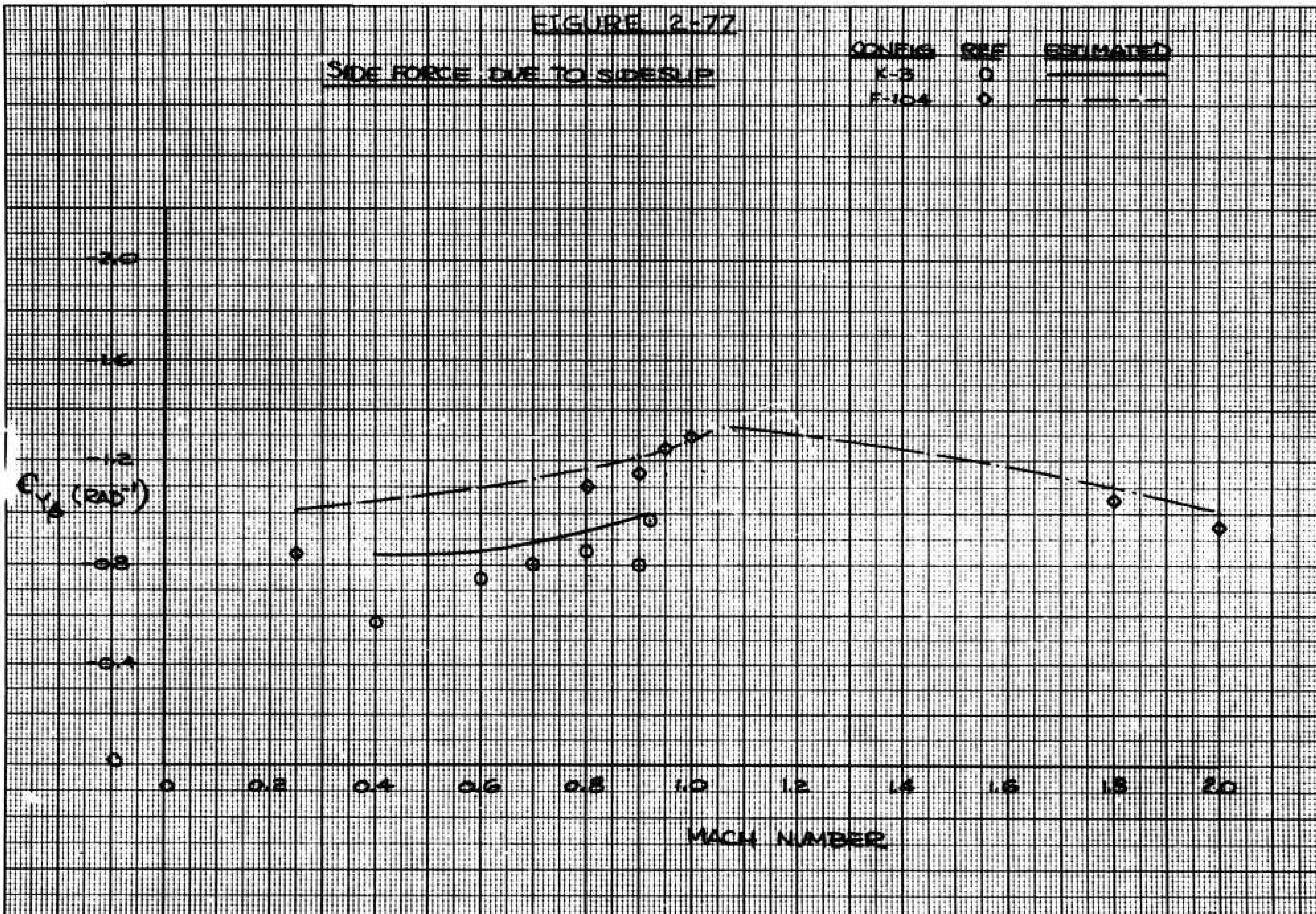


FIGURE 2-77

SIDE FORCE DUE TO SIDESLIP

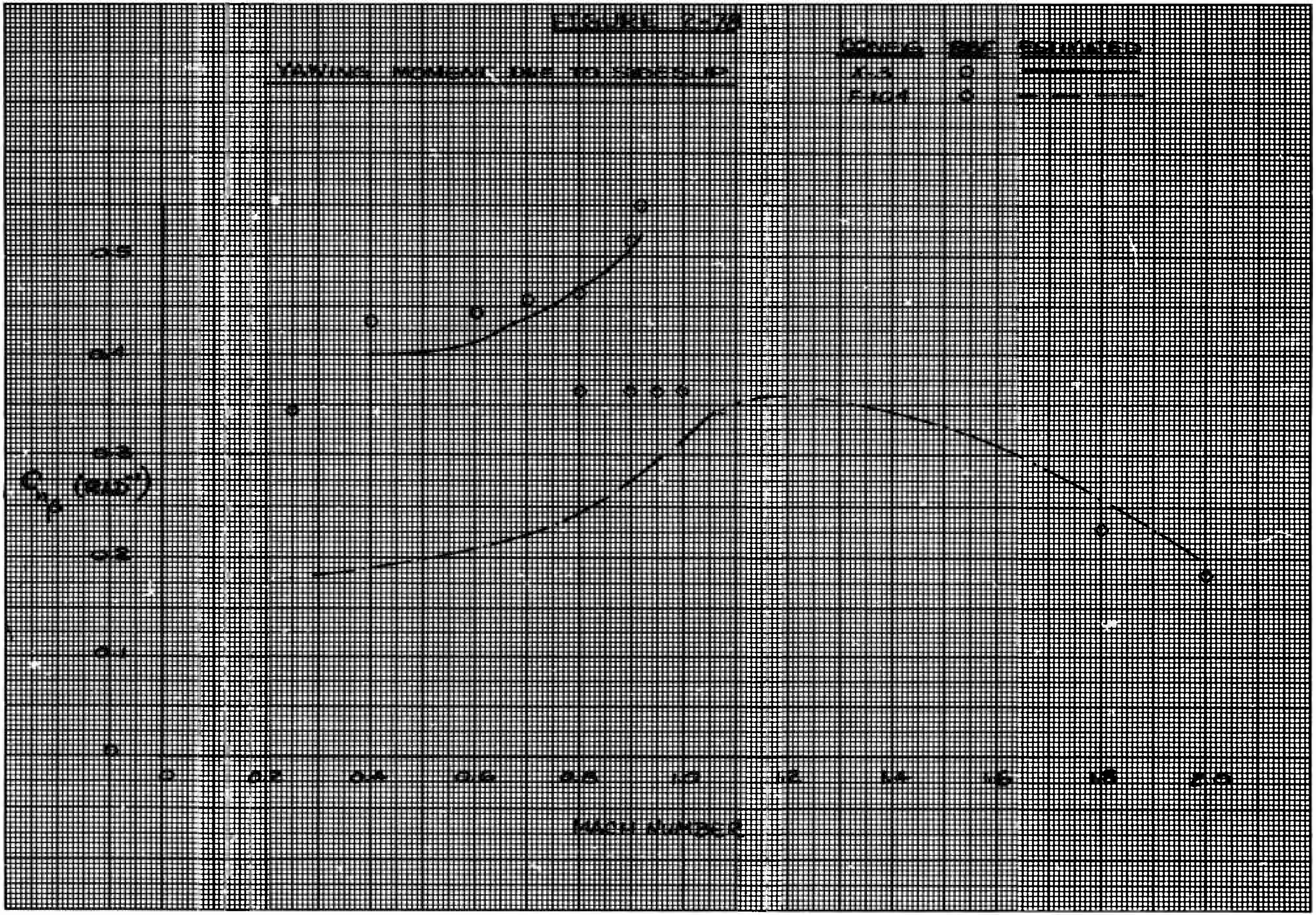


FIGURE 2-78
YAWING MOMENT DUE TO SIDESLIP
CONFIG
ESTIMATED
F-104
C_{n_β} (RAD^{-1})
0
.1
.2
.3
.4
.5
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

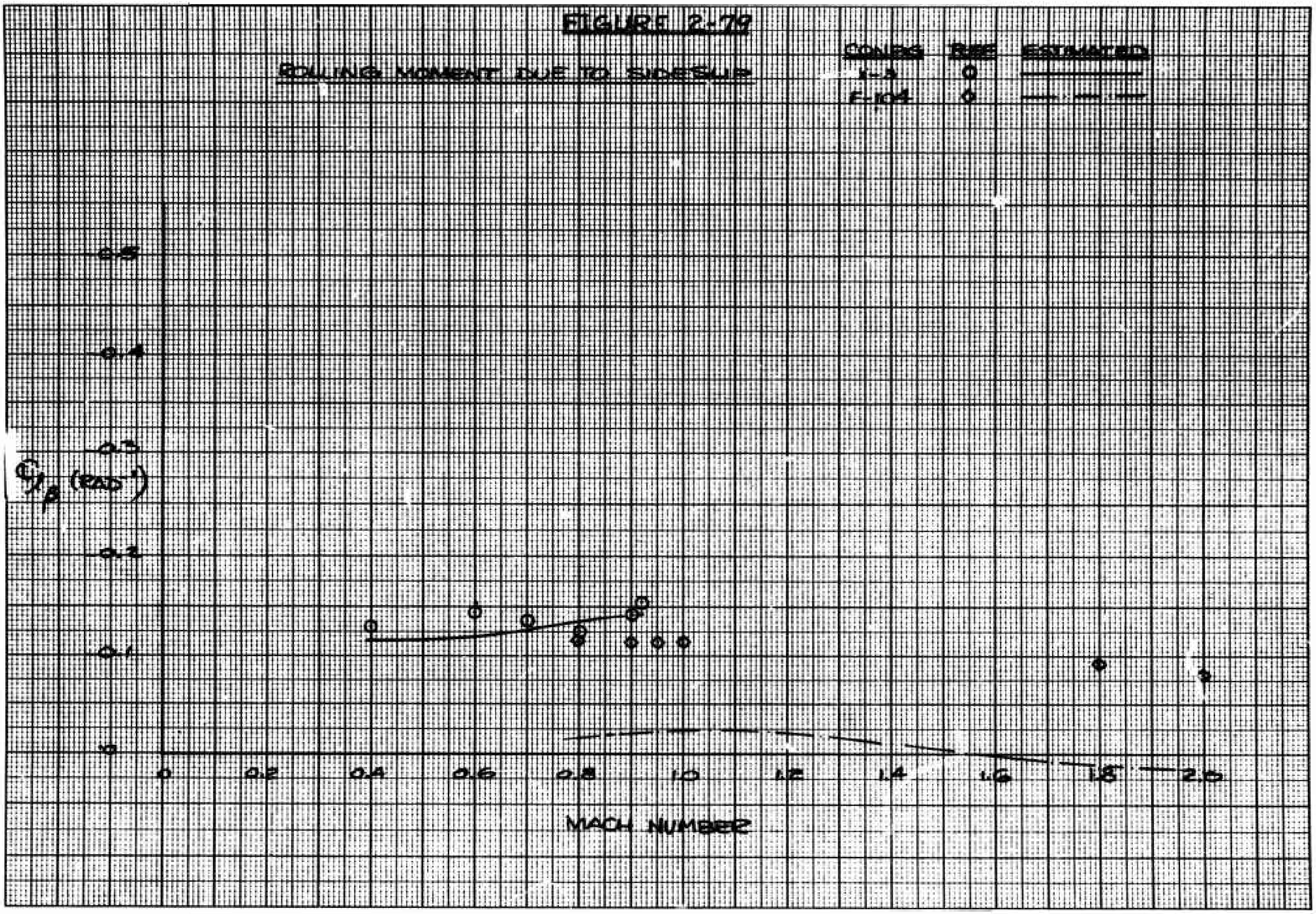


FIGURE 2-79
ROLLING MOMENT DUE TO SIDESLIP
CONFIG REF ESTIMATED
F-104
C_{l_β} (RAD^{-1})
0.5
0.4
0.3
0.2
0.1
0
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
MACH NUMBER

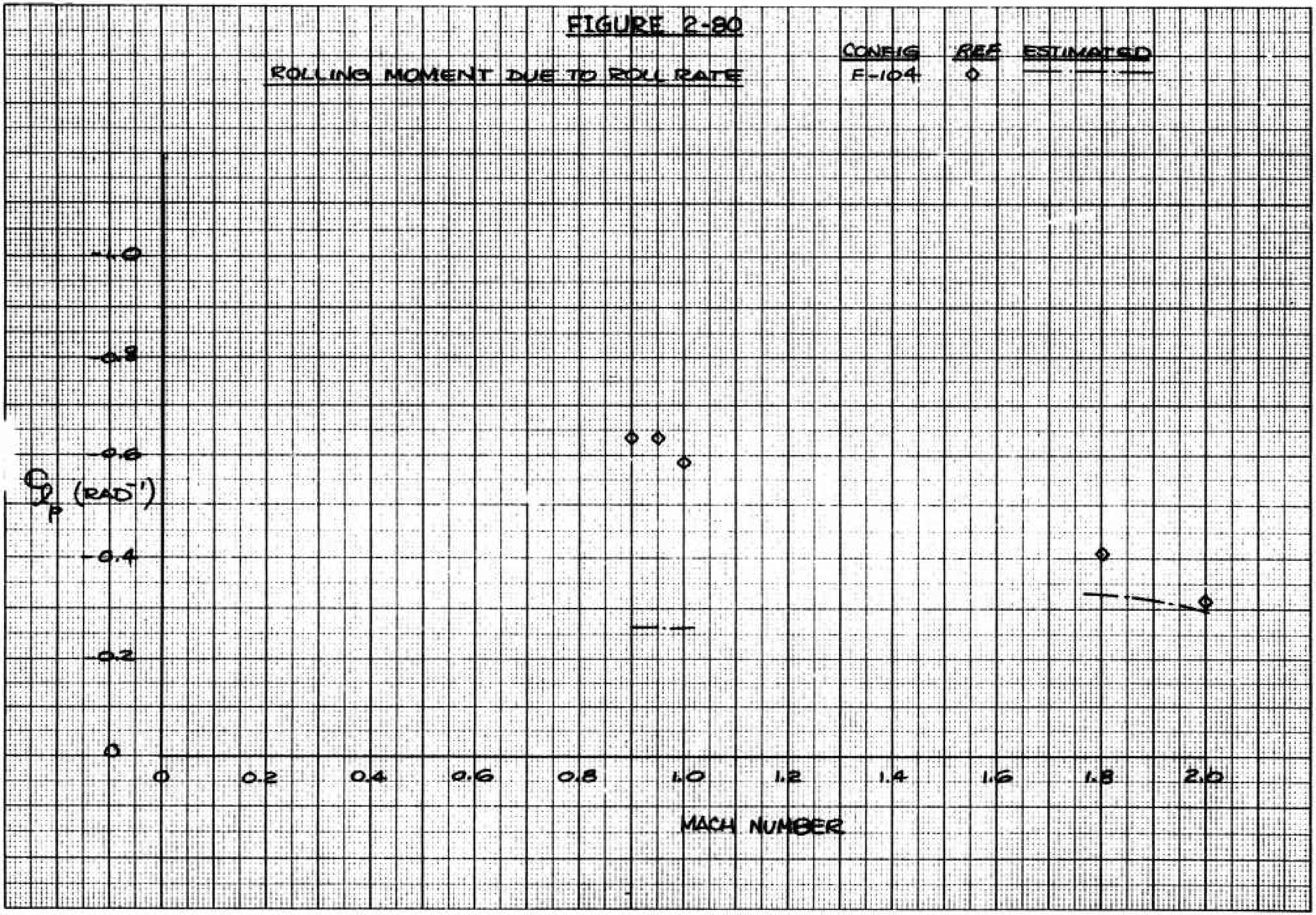


FIGURE 2-80

ROLLING MOMENT DUE TO ROLL RATE

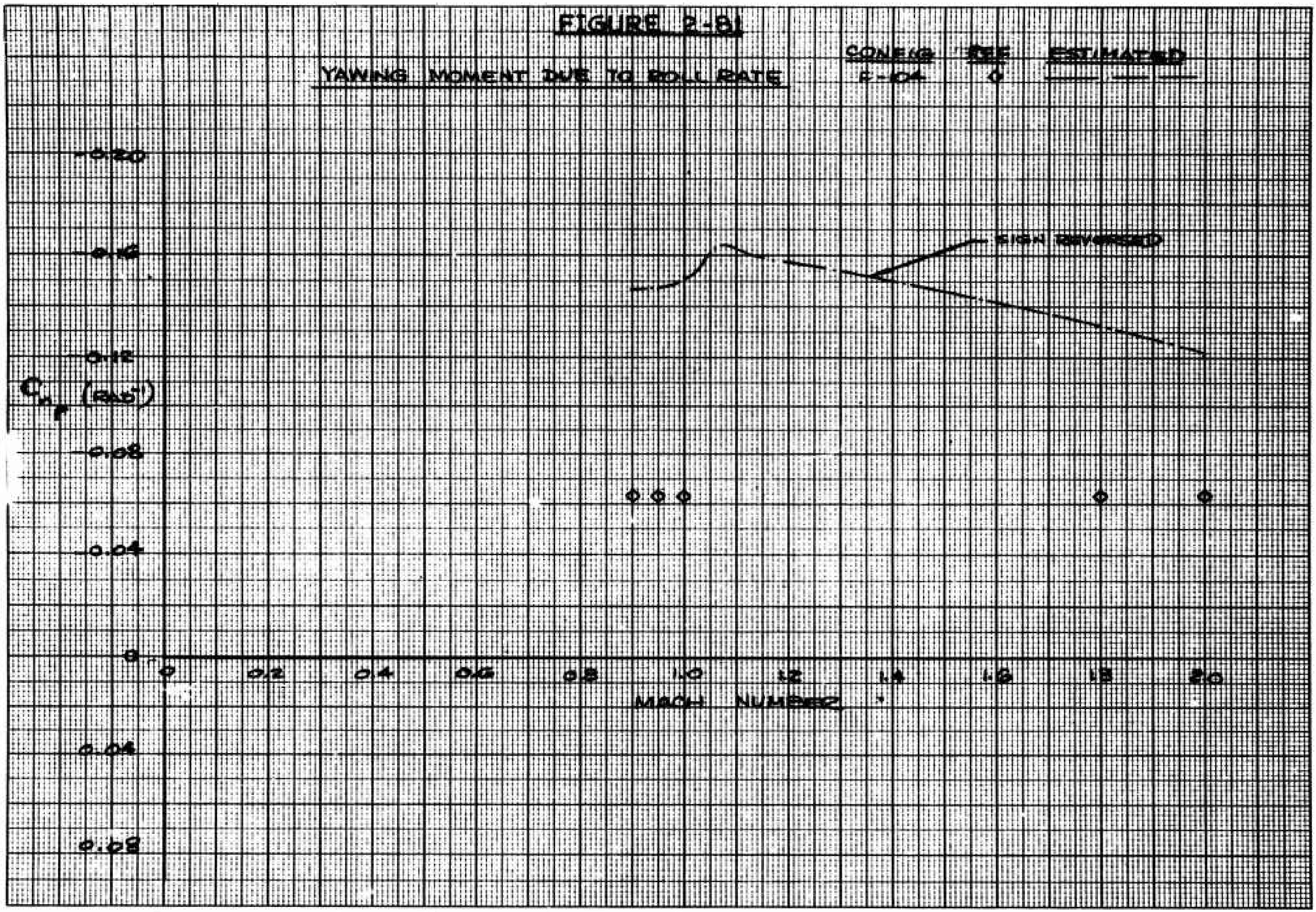


FIGURE 2-81
YAWING MOMENT DUE TO ROLL RATE
CONFIG
F-04
REF
ESTIMATED
SIGN REVERSED
-0.20
-0.16
-0.12
C_{n_p} (RAD^{-1})
-0.08
-0.04
0
0.04
0.08
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

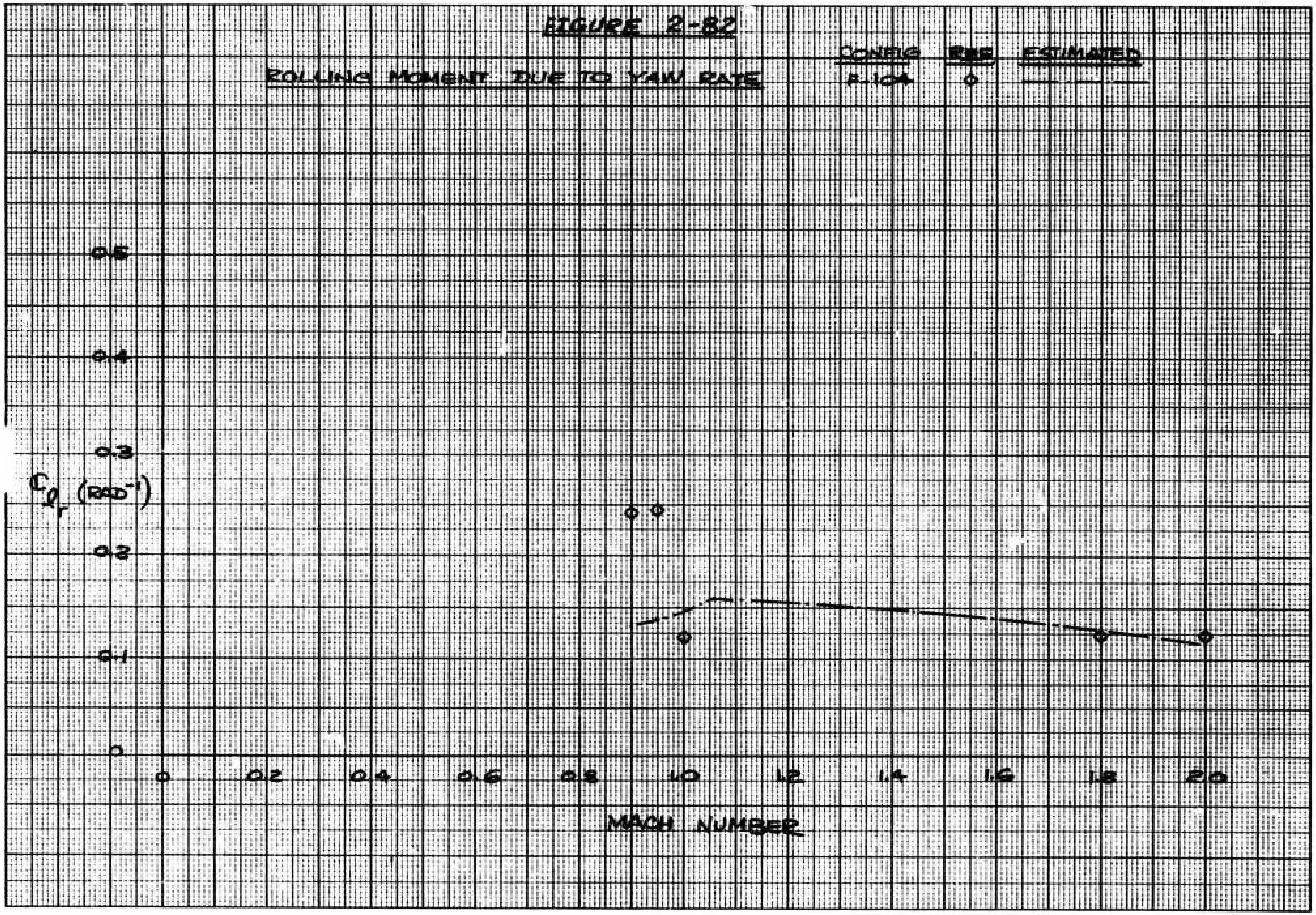


FIGURE 2-82
ROLLING MOMENT DUE TO YAW RATE
CONFIG
ESTIMATED
0.5
0.4
0.3
C_{ℓ_r} (RAD^{-1})
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

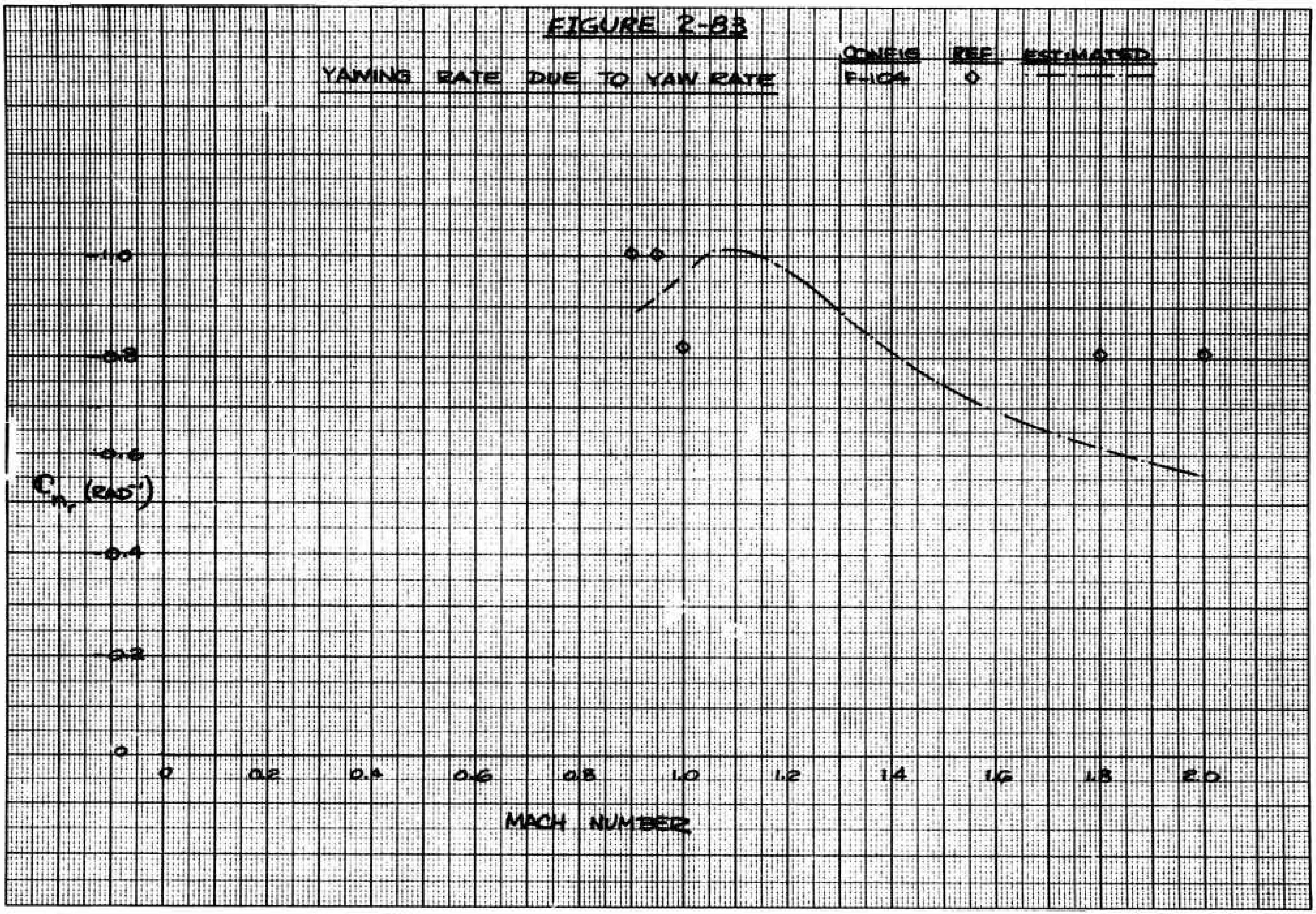


FIGURE 2-83

YAWING RATE DUE TO YAW RATE

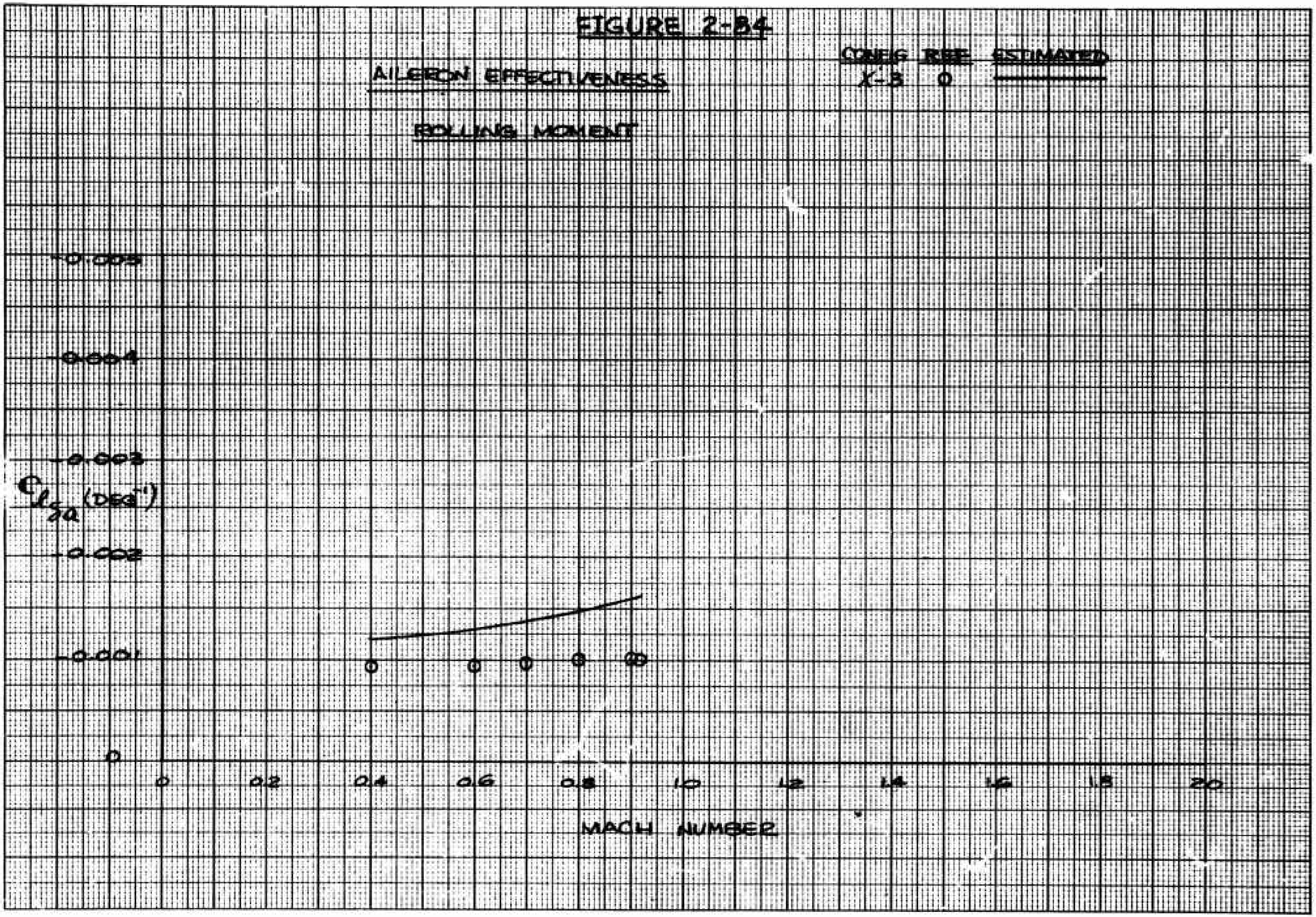


FIGURE 2-84
AILERON EFFECTIVENESS
ROLLING MOMENT
CONFIG REF ESTIMATED
X-3 O
$C_{l_{\delta a}}$ (DEG^{-1})
-0.005
-0.004
-0.003
-0.002
-0.001
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

TABLE 2-39

CORRELATION OF THE NAVION AIRCRAFT LONGITUDINAL AND AND LATERAL AERODYNAMIC PARAMETERS

PARAMETER	FLYING QUALITIES PROGRAM	REFERENCE 1*	REFERENCE 2*
C_{L_α}	.0919	.0913	.0755
C_{m_α}	-1.02	-1.26	-0.77
$C_{m_{\dot\alpha}}$	-6.40	-6.50	-22.40
C_{m_q}	-15.27	-13.00	
$C_{z_{\delta_E}}$	-.00847	-.00698	-.00892
$C_{m_{\delta_E}}$	-.0213	-.0244	-.0248
C_{Y_β}	-.341	-.35	-.60
C_{n_β}	00268	.049	.073
C_{ℓ_β}	-.062	-.06	-.07
C_{ℓ_p}	-.43	-.45	-.49
C_{n_p}	-.0147	-.024	-.04
C_{ℓ_r}	.051	.04	.11
C_{n_r}	-.083	-.082	-.090
$C_{n_{\delta_a}}$	-.000076	-.000087	-.000070
$C_{\ell_{\delta_a}}$	.00248	.0026	.00268
$C_{Y_{\delta_R}}$	.00127	.0014	.0058
$C_{n_{\delta_R}}$	-.00063	-.0014	-.0011
$C_{\ell_{\delta_R}}$	.00003	.0052	.00045

* References

1. Anon.: USAF Stability and Control DATCOM
2. NASA TN D-6643 (Reference 3.56)

SECTION 3

METHODOLOGY ASSESSMENT

The correlation studies have indicated certain factors have a significant influence on the validity of the correlation studies and should be carefully considered when evaluating the results. Initial evaluation indicates that large differences may result from several sources, such as, extracting data from the reference sources, matching test Reynolds number, tail arms due to a.c. prediction techniques, body side area, force break Mach numbers, apparent mass factor due to addition of a horizontal tail in presence of the body, methodology basis, wing-body contribution to the longitudinal dynamic characteristics and adequate configuration representation.

A brief summary of these factors is presented in the following sections.

3.1 REYNOLDS NUMBER EFFECTS

The Reynolds number influences the section lift curve slope factor and the yawing moment due to sideslip. The effect on lift curve slope appears to be insignificant but the yawing moment is very sensitive as evidenced by the factor (K_{R_ℓ}) presented in Figure 5.2.3.1-9 of the DATCOM. The program input was modified to provide for inputing an altitude-Mach number schedule in order to have a better match of test conditions.

3.2 BODY SIDE AREA EFFECTS

The wing-body yawing moment due to sideslip C_{n_β} is directly proportional to the body-side area. A good representation of the side area must be available in order to provide good correlation of this derivative. A new input has been added to the body input to provide for a more exact accounting of body side area. The new input is the height of the fuselage at the base and is designated HAFT.

3.3 TAIL ARM EFFECTS

The moment arms utilized to evaluate the contribution of the wing-body, horizontal tail/ canard, vertical tail, ventral and the control surfaces to the aerodynamic characteristics are based on the aerodynamic center location of the particular surface under consideration. The present methodology estimates the a.c. with relatively poor accuracy and thus propagates into all moment evaluation.

3.4 FORCE BREAK MACH NUMBER EFFECTS

The force break Mach number directly influences the transonic lift curve slope and aerodynamic center location, but indirectly influences moments, both in pitch and sideslip. The methodology in the DATCOM limits the force break Mach number to 1.0, which in turn effects the force and location of the force for most high speed aircraft with wings designed to extend the drag rise to high speeds for efficient combat performance. The correlations indicate for most cases, that as the transonic speed approaches 1.0 from either the subsonic or supersonic Mach number, the percentage error increases which supports the above observation.

3.5 HORIZONTAL TAIL APPARENT MASS FACTOR EFFECTS

One parameter which significantly effects the supersonic sideslip characteristics and warranted mentioning is the apparent mass factor due to the addition of a horizontal tail in presence of the body ($K_{H(B)}$). This term is obtained from Figure 5.3.1.1-2500 of the DATCOM and indicates a large variation if the tail is off the centerline. The correlation studies have indicated that this term results in increments that appear to be too large. A more complete data base on a wide variety of configurations would be required to confidently make any judgements as to any modifications.

3.6 EXTRACTION OF TEST DATA

The extracting of the test data from the reference source is another area where discrepancies may occur. Tables 2-40 through 2-43 illustrate the differences that may result when different people extract the data. The first line in the tables are the calculated and test values from the present study. The second line lists of values from the DATCOM with the appropriate section and reference denoted in the reference column. The correlations presented in the DATCOM were done by hand and therefore only a limited number of cases could be utilized. The chance of discrepancies in the various cases is also much greater than with the present computer system.

3.7 METHODOLOGY BASIS

The manner in which the methodology was derived can make a difference in the accuracy of the correlations. It was clearly observed during the present correlations that the location of the aerodynamic center based on the mean aerodynamic chord, for most cases evaluated, was more than plus or minus ten percent of the test results. Further investigations provided enough information to rationalize that these results were possible. The methodology was developed based on correlations of the a.c. as a function of root chord and was constructed to evaluate within plus or minus ten percent for the cases evaluated. Since, for most basic configurations the ratio of the root chord to the mean aerodynamic chord is between 1.5 and 2.5, it is logical that the percent error of the a.c. based on $\bar{c}$ will be higher. The cranked wing data

presented in Table 2-8 is illustrative of this shift in the aerodynamic center. The configuration presented in Reference 4.2 of the bibliography was utilized. The spanwise location of the reference chord is different from the basic mean aerodynamic chord, therefore, the data had to be shifted in order to compare with the predicted data. It appears that this reference system is utilized by the NASA for all the cranked wing configurations.

For wings that have the tips cranked forward the methodology in the DATCOM predicts the aerodynamic center at an extreme aft position compared to test data. The correlations which formed the base for the methodology did not consider configuration of this class (Reference 5.6 and 4.1).

Most of the methodology in the DATCOM was developed utilizing a relative small data base which limits the suggested accuracy to a small number of configurations. For cases outside this range the percentage error between calculated and test data rapidly increases. This has been evidenced throughout the present study where the methodology predicts one configuration reasonably well and not others.

3.8 WING-BODY CONTRIBUTION TO THE LONGITUDINAL DYNAMIC CHARACTERISTICS

The correlation studies for the longitudinal dynamic characteristics indicate that the wing-body contribution is too large for configurations that have horizontal tails. In some cases the wing-body values are of the same magnitude as the tail terms. Past experience has indicated the wing-body contribution is approximately ten percent of the tail terms. Further studies are required to develop a more adequate data base to provide guidance in modifying the methodology.

3.9 CONFIGURATION REPRESENTATION

The results of the correlation studies depend on how adequate the configuration can be described. It was evident from the present study that it is extremely difficult to find test data that systematically varied configuration parameters and present sufficient description of the test model. The NASA reports are the only source that has sufficient data to perform the required parametric variation. The configuration descriptions are not complete in the references and the user has to scale the small drawing in the report to obtain the desired input data. This procedure introduces errors into the correlations that must also be considered in the methodology evaluation.

3.10 METHODOLOGY UTILIZATION

It is apparent from the previous discussions that the inaccuracies of the correlations are not traceable to one particular source. Many of the items of Sections 3.1-3.9 and others that are not as visible, are compounded for some aerodynamic characteristics.

It is imperative that care should be taken in making judgements on the validity of any methodology developed on a limited data base as much of the current methodology in the DATCOM has been. When adequate correlations have been conducted and carefully analyzed, the methodology usually provides adequate results. A good example is the lift curve slope for which many years of study has gone into the development of the methodology.

The estimating techniques of the Flying Qualities Program should receive more exposure and evaluation before a conclusive decision be made as to its validity as a tool to be utilized in a predesign environment.

Even though the correlation studies have indicated the accuracy levels are not as good as the user would like, the Flying Quality Programs utility for application in preliminary design is unique. In the past the engineering analyst would have had to utilize the same methodology and perform cumbersome hand computations to provide a data base to perform aircraft handling qualities analysis. The FQP has mechanized these computations which allows the user to rapidly and economically evaluate aircraft configurations.

Viable uses of the Flying Qualities Program are demonstrated in (1) providing initial estimates of early predesign configurations, (2) evaluation of effects of configuration changes from a known data base, (3) quick analyses of a configuration to provide guidance to the designer in configuration definition studies. These applications have successfully been applied by Convair Aerospace in their Cruise Missile and VFAX aircraft definition studies.

TABLE 2-40

Wing-Body Lift Curve Slope Accuracy Substantiation Data

Ref.	Config.	M	C_{L_α} (deg^{-1}) Calc.	C_{L_α} (deg^{-1}) Test	Percent Error	Comment
4.1 DATCOM 4.1.3.2(29)	53-32	0.6	.0623	.0595	4.7	Cranked Wing-Body
			.0582	.0590	-1.4	
		0.8	.0656	.0650	0.9	
			.0657	.0670	-1.9	
		0.9	.0672	.0720	-6.7	
			.0728	.0740	-1.6	
4.2 DATCOM 4.1.3.2(27)	W_1B_5	0.6	.0484	.0490	-1.2	
			.0486	.0490	-0.8	
		0.8	.0503	.0490	2.7	
			.0536	.0490	9.4	
		0.9	.0513	.0520	-1.3	
			.0587	.0520	12.9	
		1.41	.0459	.0455	0.9	
			.0456	.0433	5.3	
		2.01	.0394	.0352	11.9	
			.0401	.0355	13.0	
5.6 DATCOM 4.1.3.2(26)	Cranked	0.8	.0772	.0775	-0.4	
			.0755	.0750	0.7	
		0.85	.0793	.0820	-3.3	
			.0773	.0830	-6.9	
		0.90	.0815	.0840	-2.9	
			.0845	.0870	-2.9	

TABLE 2-41

Wing-Body Mean Aerodynamic Center Location Accuracy
Substantiation Data

Ref.	Config.	M	$X_{ac}/\bar{c}_W$ Calc.	$X_{ac}/\bar{c}_W$ Test	Percent Error	X_{ac}/c_r Calc.	X_{ac}/c_r Test	Percent Error	Comments
4.2	W_2B_2	0.6	.420	.444	-5.4	.778	.791	-1.6	Cranked Wing-Body
DATCOM			-	-	-	.770	.797	-3.4	
4.3.2.1(17)		0.8	.433	.454	-4.6	.785	.797	-1.5	
			-	-	-	.780	.802	-2.7	
		0.9	.443	.468	-5.3	.791	.806	-1.9	
			-	-	-	.784	.804	-2.5	
		1.41	.475	.582	-18.3	.810	.874	-7.3	
			-	-	-	.843	.872	-3.3	
		2.01	.491	.566	-13.3	.820	.864	-5.1	
			-	-	-	.853	.864	-1.2	
4.7	60-25	0.24	.434	.423	2.5	.691	.685	0.9	
DATCOM			-	-	-	.679	.683	-0.6	
4.3.2.1(22)									
	60-75		.272	.311	-12.5	.836	.868	-3.7	
			-	-	-	.845	.900	-6.1	
	60-30		.362	.389	-6.9	.645	.660	-2.3	
			-	-	-	.654	.660	-0.9	
	60-70.5		.318	.359	-11.4	.717	.748	-4.1	
			-	-	-	.690	.749	-7.9	
5.2	High Taper	0.6	.181	.40	29.3	.380	.353	7.6	Straight Taper Wing-Body
DATCOM			-	-	-	.389	.350	11.1	
4.3.2.1(9)									

TABLE 2-42

Wing-Body Sideslip Characteristics Accuracy Substantiation Data

Ref.	Conf.	M	C_{Y_β} (rad^{-1}) Calc.	C_{Y_β} (rad^{-1}) Test	Percent Error	C_{n_β}(rad^{-1}) Calc.	C_{n_β}(rad^{-1}) Test	Percent Error	C_{l_β}(rad^{-1}) Calc.	C_{l_β}(rad^{-1}) Test	Precent Error	Comment
3.18	High Wing	0.25	-.156	-.149	4.7	-.060	-.069	-13.0	-.030	-.0029	-	Straight Tapered Wing
DATCOM	FR=12		-.147	-.149	-1.3	-.081	-.069	17.4	-.030	-.029	3.4	
5.2.1.1(5)		0.80	-.172	-.132	30.3	-.070	-.074	-5.4	-.030	-.035	-14.3	
5.2.3.1(13)			-	-	-	-	-	-	-.030	-.034	-11.8	
5.2.2.1(17)		0.90	-.179	-.132	35.6	-.071	-.076	-6.6	-.030	-.038	-21.1	
			-	-	-	-	-	-	-.030	-.038	-21.1	
3.20	Λ=0-W2	0.17	-.273	-.241	13.3	-.043	-.069	-37.7	-.044	-.046	-4.3	
DATCOM			-.215	-.229	-6.1	-	-	-	-	-	..	
5.2.1.1(3)	W1		-.174	-.138	-26.1	-.043	-.052	-17.3	0.0	0.0	-	
			-.138	-.138	0	-.049	-.052	-4.4	-	-	-	
	W3		-.231	-.195	18.5	-.043	-.052	-17.3	.044	.049	-10.2	
			-.183	-.195	-6.2	-	-	-	-	-	-	
5.8	High Wing	2.01	-.292	-.303	-3.6	-.100	-.109	-8.3	-.039	-.0573	-31.9	
DATCOM			-.281	-.264	6.4	-	-	-	-	-	-	
5.2.1.1(13)												
5.2.3.1(3)	Mid Wing		-.169	-.171	-1.2	-.100	-.092	8.7	0.0	0.0	0	
			-.163	-.166	-1.8	-.097	-.097	0	-	-	-	
	Low Wing		-.240	-.287	-16.3	-.100	-.092	8.7	.039	.0573	-31.9	
			-.234	-.287	-18.5	-	-	-	-	-	-	
6.1	Swept	1.41	-.265	-.258	2.7	-.072	-.086	-16.3	.032	.069	-53.6	
			-	-	-	-.087	-.086	1.3	-	-	-	
		1.61	-.265	-.258	2.7	-.074	-.095	-22.1	.032	.052	-38.5	
			-	-	-	-.087	-.095	-8.5	-	-	..	
		2.01	-.265	-.258	2.7	-.076	-.092	-17.4	.032	.046	-30.4	
			-	-	-	-.085	-.092	-7.5	-	-	-	

TABLE 2-43

Vertical Tail Sideslip Characteristics Accuracy Substantiation Data

Ref.	Config.	M	ΔC_{Y_β} (rad^{-1})		Percent	ΔC_{n_β} (rad^{-1})		Percent	ΔC_{ℓ_β} (rad^{-1})		Percent	Comment
			Calc	Test	Error	Calc.	Test	Error	Calc	Test	Error	
3.18	V_{small}	0.25	-.481	-.54	10.9	.223	.24	7.1	-.058	-.060	3.3	Small Tail
	V_{large}		-.734	-.76	3.4	.325	.31	4.8	-.102	-.091	12.1	Large Tail
6.1	Basic	1.41	-.374	-.401	-6.7	.153	.169	-9.5	-.041	-.057		Basic Tail
DATCOM			-	-	-	-	-	-	-	-	-	
5.3.1.1(17)		1.61	-.335	-.372	-9.9	.138	.160	-13.8	-.037	-.052	-28.8	
			-.368	-.37	0.5	.148	.15	1.3	-.050	-.043	16.3	
		2.01	-.270	-.258	4.7	.113	.126	-10.3	-.029	-.029	0	
			-.335	-.30	11.7	.135	.12	12.5	-.048	-.034	41.2	
	Extended	1.41	-.442	-	-	.189	-	-	-.052	-	-	Extended Tail
			-	-	-	-	-	-	-	-	-	
		1.61	-.389	-.401	-2.9	.168	.172	-2.3	-.046	-.058	-20.7	
			-.424	-.41	3.4	.176	.17	3.5	-.064	-.054	18.5	
		2.01	-.304	-	-	.132	-	-	-.036	-	-	
			-	-	-	-	-	-	-	-	-	
	127%	1.41	-.481	-.458	5.0	.203	.192	5.7	-.058	-.077	-24.6	127% Tail
			-	-	-	-	-	-	-	-	-	
		1.61	-.427	-.441	-3.2	.181	.18	0.5	-.051	-.066	-22.7	
			-.471	-.44	7.0	.193	.17	13.5	-.069	-.060	15.0	
		2.01	-.340	-	-	.146	-	-	-.041	-	-	
			-	-	-	-	-	-	-	-	-	

SECTION 4

BIBLIOGRAPHY

The bibliography is divided into eight categories as listed below:

1. High Lift Characteristics
2. Propeller Characteristics
3. Straight Tapered Wing Configurations
4. Non-Straight Tapered Wing Configurations
5. Horizontal Tail Effects
6. Vertical Tail Effects
7. Canard Configurations
8. Ventral Effects

The number of variables that were considered in the study and the constrained schedule did not allow every data reference to be analyzed.

1 - HIGH LIFT

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2. Cook, Anthony M., Greif, Richard K., and Aoyagi, Kiyoshi: Large-Scale Wind-Tunnel Investigation of the Low-Speed Aerodynamic Characteristics of a Supersonic Transport Model Having Variable-Sweep Wings, NASA TN D-2824, May 1965.

3. Hebert, J., Jr., et. al.: Stol Tactical Aircraft Investigation, Volume II Design Compendium, AFFDL-TR-73-21-VOL. II, May 1973.

2. PROPELLER

1. Weil, Joseph, and Boykin, Rebecca I.: Wind-Tunnel Tests of the 0.15-Scale Powered Model of the Fleetwings XBTK-1 Airplane Longitudinal Stability and Control, MR L5D27a, May 1945.

2. Suit, William T.: Aerodynamic Parameters of the Navion Airplane Extracted from Flight Data, NASA TN D-6643, March 1972.

3 - STRAIGHT TAPERED WINGS

1. Wiggins, James W. and Kuhn, Richard E.: Wind-Tunnel Investigation of the Aerodynamic Characteristics in Pitch of Wing Fuselage Combinations at High-Subsonic Speeds, (Sweep Series), NACA RM L52D18, July 2, 1952

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3. Spearman, M. Leroy: Investigation of the Aerodynamic Characteristics in Pitch and Sideslip of a 45° Sweptback-Wing Airplane Model with Various Vertical Locations of the Wing and Horizontal Tail (Effect of Wing Location and Geometric Dihedral for the Wing-Body Combination, M = 2.01), NACA RM L55B18, April 6, 1955.

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6. Queijo, M. J., and Wells, Evalyn G.: Wind-Tunnel Investigation of the Low-Speed Static and Rotary Stability Derivatives of a 0.13-Scale Model of the Douglas D-558-II Airplane in the Landing Configuration, NACA RM L52G07, August 27, 1952.

7. Spearman, M. Leroy: Limited Investigation of Effects of Differential Horizontal-Tail Deflection on Lateral Control Characteristics of Two Swept-Wing Airplane Models at Mach Numbers From 1.4 to 2.0, NACA RM L56I20, December 13, 1956.

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